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Firm-level Evidence for the DACH Region

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E-mail address: michael.peneder@wifo.ac.at

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Medieninhaber (Verleger), Hersteller: Österreichisches Institut für Wirtschaftsforschung • 1030 Wien, Arsenal, Objekt 20 • Tel. (43 1) 798 26 01-0 • Fax (43 1) 798 93 86 • http://www.wifo.ac.at/ • Verlags- und Herstellungsort: Wien

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

Michael Peneder[1] Spyros Arvanitis[2] Christian Rammer[3]
Tobias Stucki[2] Martin Wörter[2]

October 30, 2017

Abstract

For a large sample of enterprises in Germany, Austria and Switzerland (the "DACH" region) we study the impact of policy instruments such as energy-related taxes, subsidies, standards and negotiated agreements, or other regulations on the firm's ecological and economic performance. To identify the causal linkages, we build a system of twelve equations, first tracking 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 through which policy can 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 efficiency, technology adoption, innovation, Porter hypothesis

[1] Austrian Institute of Economic Research (WIFO), Vienna, Austria.
[2] ETH Zürich, KOF Swiss Economic Institute, Zürich, Switzerland.
[3] Center for European Economic Research (ZEW), Mannheim, Germany.

1 Introduction

The *Paris Agreement*[1] represents the most ambitious plan for transnational coordination to mitigate the perils of climate change thus far. At the same time doubts about its scope, lack of enforcement and the bottom-up approach of nationally determined contributions (NDCs) point towards its apparent limitations. Given the huge gap between the perceived need of transformation and the collective willingness to contribute to it, better knowledge about the impact of different instruments is of paramount importance to establish effective environmental policies.

Broadly speaking, societies face three paths to pursue (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.

– A second path is to change the *composition* of activities. Above a certain threshold of per capita income, environmental efficiency tends to improve, because of structural change in favour of services and preferences for a clean environment.[2] This contributes to the decoupling of the growth of emissions relative to that of output, but growth is nevertheless likely to further increase the cumulative stock of pollutants.

– *Innovation* and technological change open a third path, which enhances structural change but also reduces the emissions of given activities. At a fundamental theoretical level, it corresponds to the tendency of dissipative systems to increase the access to free energy or raise the efficiency in its use.[3] For instance, van den Bergh (2007) points at Georgescu-Roegen's (1971) emphasis on novel exosomatic instruments, which drive human development by extending its endosomatic capabilities.

The focus of our analysis is on such technological innovations. Using a large sample of firms from a new enterprise survey that was simultaneously conducted in Germany, Austria and Switzerland (the "DACH" region), we study the impacts of the adoption of "green" energy saving and related technologies (GETs). 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 distinguish between two mechanisms: 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 have the desired ecological impacts and how they relate to the firm's competitiveness.

[1]Which came into force on the 4th of November 2016 under the United Nations Framework Convention on Climate Change (UNFCCC).

[2]Grossman and Krueger (1995) suggested an inverted-U shaped relationship ("environmental Kuznets curve"). Of related interest, see also Fouquet (2014), Moosa (2017) or Halkos and Managi (forthcoming).

[3]See Georgescu-Roegen (1971), Ayres (1994), Buenstorf (2000), and Foster (2011, 2014).

The remainder of this paper is organised as follows: Section 2 briefly discusses the rationale and instruments of available policies 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, and 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 them. 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.

The principle of *sustainability* offers an alternative rationale. Solow (1992) defines it as an ethical norm of inter-generational equity: to ensure that future generations can be as well off as we are. Since the distant future is not well represented in the market and opinion surveys generally show a low concern about ecological problems (Millner and Ollivier, 2016), 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. on how to substitute for cleaner technologies or the use of renewable resources. Thus 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 related risk of irreversible, catastrophic events largely obliterate the use of expected values or market-based discount rates, instead calling for a conservationist bias (Arrow and Fisher, 1974; Weitzman, 1998; Pindyck, 2007). In other words, the principle of sustainability can require current populations to foresake own consumption possibilities to the benefit of future generations - obviously not easy to manage within a paradigm of individual sovereignty and welfare optimisation.[4]

Traditional welfare economics nevertheless has much to contribute in terms of consistent arguments, which should support policy in choosing efficient instruments. Most economic rationales 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

[4]See, e.g., Geisendorf (2016) for an agent-based model about the formation of environmental beliefs.

in which individual enterprises do not bear the cost for the 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), and 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.[5] 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 for society. As a consequence, pure market based allocation based on the individual calculus of marginal cost and return provides insufficient incentives to mitigate environmentally harmful activities or to invest in environmental technologies and practices.

But the rationale for public intervention should no longer be confined to static welfare gains. In the presence of increasing returns the ecological problems are amplified by path-dependency and lock-in effects. One must therefore expect that a focus on cost-efficiency and the correction of relative prices alone won't suffice to change trajectories (van den Bergh, 2007). For instance, Gillingham and Palmer (2014) refer to "behavioral failures" to account for the frequent undervaluation of future cost-savings by consumers that leads to a suboptimal rate of adoption of energy efficient technologies. Conversely, Peneder (2017) advocates to replace the various "rationalities of failure" and instead focus on the system's ability to evolve along desired objectives of society, which in this case is to manage an effective energy transition. Highlighting the impact of lock-in and path dependence in a two-sector model of directed technological change Acemoglu et al (2012, 2016) assume that a unique final good is produced by either an old (and dirty) or a new environmental friendly technology. The accumulation of past knowledge favors the traditional production method and policy must intervene to break the lock-in. Provided such a dynamic rationale of public interventions, delays in their implementation increase the advantage of the old technology and therefore the overall cost of transition. Furthermore, if the two technologies are perfect substitutes, only a temporary intervention is needed until the dynamic advantages operate in favor of the new technology. Conversely, public interventions have to be permanent, if the two technologies are not sufficient substitutes. Only if the old and the new technology are complements, long-run growth must stop in order to avoid environmental disaster – which brings us back to the first of the three avenues highlighted by Frankel (2004).

Policy can choose from a variety of instruments,[6] which can be organised under the header of several broad categories: The first is *public funding*, e.g. in the form of grants,

[5] Ostrom (1990, 2010) demonstrated the possibility of local communities to contain these by means of self-organized rules and institutional arrangements. However, for climate change, known as the "ultimate commons problem" (Stavins, 2011), the community affected is global and potential barriers for coordination and governance are immensely more difficult. Though global coordination has proven effective, for instance, in containing the emissions of FCKWs, the implied costs were on a much smaller scale and new technological solutions turned out to be more readily available than anticipated.

[6] See, for example, Goulder and Parry (2008) or Metcalf (2009).

preferential credit or tax allowances. It is a popular tool of technology policy to enhance productive capabilities and foster structural change. 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 and to foster the transition towards environmental sustainability.[7]

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.[8]

Different from price-based interventions, rules and other quantity-based *regulations* target specific ecological impacts, e.g. by banning certain inputs and processes, or defining the caps of allowed emissions. While difficult to explain in terms of market failure, from an evolutionary perspective their function is to shape the selection environment by defining what firms are allowed to do or not. If permits are tradeable, the policy additionally aims for cost-efficiency by affording the market participants more flexibility to adapt. As with environmental taxes and duties, the added flexibility of tradeable permits increases efficiency most for heterogenous firms and technologies.[9]

Finally, *standards* and negotiated (“voluntary“) agreements within the industry combine the advantages of lower administrative costs and certainty of required ecological performance with the informational advantage of the industry's stakeholders about technological opportunities and the cost of implementation. Again these are difficult to explain in terms of market failure, but reflect certain advantages of self-organization.

Business tends to prefer standards over the incentive-based policies of taxes and tradeable permits. They perceive these to be less expensive, because they involve the abatement costs of reducing pollution to a specified level, whereas auctioned permits and taxes additionally require business to pay for polluting *up to* that level.[10] 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 power of different stakeholders.

[7] A major drawback of public funding is the distortion of output prices, which can imply too much consumption of goods and services from environmentally harmful production. Further distortions may arise in other markets from the raising of public funds via taxes.

[8] Cost-efficiency is a major advantage of taxes and duties, since firms can select the aspired level of abatement and means of achieving it. This provides them with the flexibility to account for particular opportunity costs in their operations and thus optimize the overall outcome. Furthermore, the incentives to invest in abatement continuously rise and fall with the targeted inputs or emissions.

[9] See, e.g., Haab and Whitehead (2017) or Schmalensee and Stavins (2017) for two recent and very positive assessments of market-based instruments in the USA.

[10] Buchanan and Tullock (1975), Keohane et al. (1998).

A common problem, however, is that mandatory standards typically affect only a certain technology or prescribed level of performance, but fail to induce further abatement activities (as the price-based instruments would do).

3 Heuristics and hypotheses

The core question of this 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 desired ecological impacts, the 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 increasing the extensive and/or intensive margins of adoption. Second, whether the induced activities actually lead to the desired ecological effect of boosting energy efficiency and reducing carbon emission.[11] 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 is comprised of nine equations that explain the extensive margin of adoption for various areas of technology and the intensive overall margin 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, 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 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 impact. 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 with respect to effects. Given the limitation of the purely cross-sectional data at hand, a credible structure of exogenous

[11] 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).

effects seems essential to approaching a meaningful identification.

[Insert Figure 1 about here]

Another means of staying 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 highlights their relevance to the overall argument.

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

- **Extensive margin** ($H1$): Policy raises the propensity to adopt new GETs. It must be rejected, if policy has no significant impact or decreases the probability of adopting new GETs.

- **Intensive margin** ($H2$): 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 ($H3$): 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), 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. The theoretic model and numeric simulations of Acemoglu et al (2012, 2016) support the idea that a combination of policies is preferable to choosing only one instrument. Furthermore, from the discussion in the previous section one can expect that standards primarily affect the extensive margin of adoption, whereas subsidies and taxes may exert more influence on its intensive margin. Given the previous considerations, we also expect standards to be the most commonly relevant factor in the adoption of new GETs.

A further two hypotheses address the *ecological impacts* of adoption:

- **Impact on energy efficiency** ($H4$): The adoption of GETs increases the energy efficiency of firms. It must be rejected, if either kind of adoption does not significantly increase it.

- **Impact on carbon emissions** ($H5$): 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). However, these social benefits are largely external to the individual firm, which bears the private cost of abatement (Pasurka, 2008).[12] The immediate impact of regulation is thus 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 fewer constraints. This argument leads us to the first of three competing hypotheses:

– **Conventional trade-off hypothesis** ($H6a$): 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) argue to relax the conventional trade-off between competitiveness and environmental policy. They demonstrate how well-designed, preferably incentive-based regulations can alert individual companies, which are 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 incentives for own innovation, the meaning of innovation is not exactly specified in their analysis. For example, when Porter and van der Linde refer to the benefits of regulatory signals with respect to 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** ($H6b$): 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 has triggered much controversy and has provided a fruitful platform for further research (Goldstein, 2002; Ambec et al., 2013). It has offered stronger theoretical explanations[13] and robust empirical support for a weaker restatement, which predicts a positive impact of environmental regulation on innovation (Jaffe and Palmer,

[12]The adoption of energy-saving technologies is a special case, since it also reduces expenditures on current operations. This effect, however, has already been covered by the above hypothesis on energy efficiency. When we address 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.

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

1997). Evidence of its initial “strong“ prediction of a positive impact on competitiveness is, however, mixed.[14]

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 needs and incentives are similar for firms operating within the same market, leaving little scope for differential impacts. Finally, considering the special nature of GETs, where the increased 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** ($H6c$): The adoption of new GETs does not significantly 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 as manufacturing, energy supply, water supply, and waste management) and half to services (including construction).[15]

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 the relevance to their business on a three-point Likert scale.[16] While the subjectivity of responses may limit comparability across firms (Bertrand and Mullainathan 2009), there are two

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

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

[16]See Lanoie et al. (2011) or Stucki and Woerter (2016) for similar approaches.

advantages of our research design. First, we are able to cover all types of policies on the same scale. Second, we can also establish the relevance of energy policies 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.[17]

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

Among the inducement factors, we distinguish five types: (a) energy-related taxes and duties; (b) regulations on energy use, such as emissions caps and certificates;[18] (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 and 2 about here]

For firm *activities* the survey was designed to provide additional information on the adoption of certified management systems or other measures for the regular audit of energy use and environmental impact (Adp_i^{ems}). With regard to the introduction of green energy technologies (GETs), we collected information on 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 of whether and to what degree the adoption of new GETs has improved performance with regard to energy consumption per unit or process, 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 the adoption of GETs.

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

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

5 Econometric model

Turning to the econometric specification, we again begin with the impact of policy on adoption. On the left side, we find the dependent variables for each of the n equations. On the right 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.

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

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:[19]

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

Reflecting the different dimensions of the explanatory variables in equations (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 side sum up to k.

[19] See Capellari and Jenkins (2003).

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:

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

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 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 GETs. Among these, 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 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, or bearing, of taxes.

[Insert Table 3 about here]

Among all GET-adopting firms, about 24% claim that energy efficiency was a primary motive. 43% of the respondents consider it a secondary impact and 33% report that both applies. Genuine energy-related purposes of adoption were particularly strong for renewable energy (Table 4). In the fields of production, buildings and transport no more than 27% claimed that energy efficiency was the primary objective; for 35% to 38% it was a secondary effect. For the remainder both applied. New GETs in the field of ICT show the largest share of firms, where energy efficiency was secondary to other purposes.

Less than 10% of adopting firms report that it did not improve their energy consumption per unit or process, and about 25% can't tell. Conversely, 36% report that their energy efficiency has improved and 30% that it has much improved due to the adoption. Firms that introduced new GETs in the field of production are most positive about improvements in energy efficiency. About 41% say that it has improved and close to 35% affirm that it has even much improved.

For carbon emissions the perceived impacts are similar but somewhat lower. Only 13% report that emissions per unit or process have not improved. 39% of respondents cannot say, which leaves 48.5% of adopting firms to assert a positive impact of adoption. Among the different technology fields, the strongest impacts are perceived in transport.

Finally, with regard to the impacts on the firm's competitiveness, 21% say that it was negative, whereas 23% cannot tell. Again, this leaves only a small majority to those firms that actually report a positive effect. Moreover, the impacts of new GETs on the competitiveness of the firm show little variation between different technological areas and are spread rather evenly across the four categories offered.

[Insert Table 4 about here]

To summarize, the perceived importance 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. A majority of firms concedes that energy efficiency was not the sole or primary objective of adopting GETs and many of them cannot assess the impacts asked. However, the ratio of firms, who explicitly reported a positive impact, and those, who explcitly denied it, reveals sizable positive effects on energy efficiency and carbon emissions as perceived by the firms, but considerably less so for their competitiveness.

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 increases the firm's probability of adopting 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 or 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 impact 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), while neither displays a significant impact on the extensive or 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* only affect 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 becomes insignificant if we include own innovations in GET among the explanatory variables.

Among the 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. [20]

[Insert Tables 5 and 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 acting as 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 one half. We therefore display the outcome in two separate columns of Table 5. This also serves as a test of the 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), exhibiting 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.[21]

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

[21] See Wörter et al (2016) for a discussion of the energy policies in the three countries.

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 significantly 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 importance of customer demand for energy efficient products and services, the overall intensive margin of adoption, and the extensive margin in the area of buildings. For firms that have expressed a concern about energy shortages, the ecological impacts are more often only a secondary effect (windfalls). These 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 without enhancing its energy efficiency.

With regard to the impact of new GETs on the firm's competitiveness, the findings support the hypothesis of a largely neutral effect of the adoption of new GETs on the competitiveness of the average firm. This points towards the general fact that 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 only apply 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 in adopting new GETs, while significantly decreasing their 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 result in any pronounced difference. The most informative tests of the robustness of the impact equations are those using multinomial logit regressions (Tables 8 to 10 in the Annex).

7 Summary and conclusions

We have 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. Arguing that the principle of sustainability goes beyond straightforward applications of welfare economics, the theoretic rationales of public intervention were discussed in terms of the traditional double-externality problem as well as an evolutionary perspective emphasising uncertainty, path dependence and myopic behaviour. While cost-efficiency and individual incentives are of undiminished importance to it, the evolutionary rationale offers a more comprehensive approach (Peneder, 2017). In addition to market based instruments, such as tradable permits, and administrative price interventions, such as taxes and subsidies, it enables us to understand the role of outright public regulation in order to shape the selection environment, or that of negotiated "voluntary" standards to exploit benefits of self-organization.

The empirical basis is a new enterprise survey that was simultaneously conducted in Germany, Austria and Switzerland (the DACH region). A quasi-system of twelve equations aims to identify the main effects, first tracking 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 and intensive margin of the adoption of new GETs, however, not uniformly and only by means of differentiated impacts of the various instruments. In turn, the adoption of new GETs contributes significantly to improving energy efficiency and reducing carbon emissions, confirming its positive overall ecological impact. Finally, the findings suggest that the adoption of new GETs has a largely neutral impact on the competitiveness of the average firm. Taken together, these findings strongly support the call for active public policies to foster the needed energy transition.

The analysis furthermore demonstrates how different instruments bring distinct strengths and weaknesses to the policy table. It supports the theoretical rationale of Acemoglu et al (2012, 2016) that a combination of tools is the most effective means to redirect technological change towards cleaner production. In other words, policy is likely to be most effective if it applies price-based instruments, such as public funding and taxes, together with quantity-based regulations, such as negotiated standards or tradeable permits. In practice, firms are most often affected by standards. This reflects the practical relevance of detailed technical rules, but also points at likely welfare losses from the insufficient use of incentive-based instruments.

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Compliance with ethical standards

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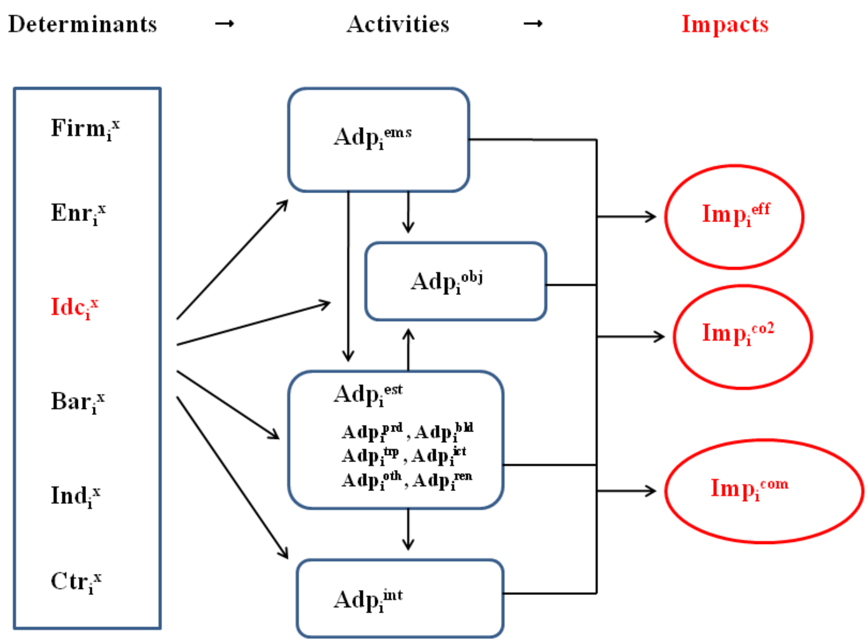
Figures and tables



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	Importance of high and volatile energy prices (2012 to 2014; not/somewhat/highly relevant)
Enr_i^{sht}	Energy shortages	Importance 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	Importance of customer demand for energy efficient goods and services (2012 to 2014; see above)
Idc_i^{pfu}	Public funding	Importance of energy related public funding (see above)
Idc_i^{tax}	Taxes	Importance of energy related taxes and duties (see above)
Idc_i^{reg}	Regulation	Importance of energy related regulations (see above)
Idc_i^{std}	Standards	Importance 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

Table 4: Objectives and impacts by area of GET adoption

	Production	Buildings	Transport	ICT	Other	Renewables	Total
	Share of adopting firms in %						
Primary or secondary objective							
Secondary	36.70	38.39	35.19	46.37	19.39	23.09	43.00
Both	38.13	34.73	39.35	34.29	40.82	37.69	33.40
Primary	25.16	26.88	25.46	19.34	39.80	39.22	23.60
Total	*100.0*	*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	9.99
Can't say	16.90	22.59	20.62	25.97	22.68	22.59	24.65
Improved	41.27	36.36	37.36	37.12	46.39	33.99	35.80
Much improved	34.58	32.78	32.56	27.81	22.68	33.55	29.57
Total	*100.0*	*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	12.63
Can't say	31.65	37.09	31.51	38.88	36.84	35.33	38.79
Improved	31.43	27.57	29.02	25.78	33.68	27.11	26.01
Much improved	26.60	24.05	30.11	22.66	23.16	27.78	22.58
Total	*100.0*	*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	23.22
No change	28.38	24.43	26.74	25.61	48.45	23.35	24.83
Improved	22.66	27.87	27.51	30.08	24.74	29.52	29.11
Much improved	24.09	24.09	24.88	20.73	0.00	25.99	22.83
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

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}.

Annex: Supplementary tables

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