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Barriers to Resource Efficiency Innovations and Opportunities for Smart Regulations – the Case of Germany

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Abstract

There are a variety of economic and ecological benefits to increased resource efficiency. Social, institutional and technical innovations can all contribute towards efficiency increases. Companies face different hurdles in fostering such innovation. Small and medium sized companies are subject to specific constraints that may prevent them from benefitting from innovation induced resource efficiency improvements. Qualitative interviews were conducted among German SMEs and intermediaries in order to identify barriers for resource efficiency innovations and to elaborate a policy mix at the federal level that could help SMEs to overcome these. We found five major barriers to resource efficiency innovations in German SMEs, comprising deficits in innovation culture, inter-firm cooperation along the value chain, finance, awareness and take-up of government funds. We propose a distinct policy mix as a response to this situation. The policy mix comprises the interlocking and synergistic elements of government funding schemes, innovation agents and innovation labs.

Introduction

Resource efficiency is a timely topic, both for economic and environmental reasons. Social, institutional and technical innovations can all contribute towards efficiency increases. However, much of the potential of resource efficiency innovations is not realised. Companies face different hurdles in fostering such innovation. Small and medium sized companies are subject to specific constraints that may be in the way of advancing and benefiting optimally from innovation induced resource efficiency improvements. Here, we shall expound on the reasons and potential solutions to this for the case of German SMEs. In the following we will first analyse five major barriers to resource efficiency innovations in German SMEs and then propose a policy mix designed to overcome these.

We begin by outlining the benefits and limitations of resource efficiency innovations. We will then briefly describe the role of resource efficiency in industrial policy, particularly with regard to the case of Germany. Following that, we will attend to the dynamics of the innovation process and to barriers for resource efficiency innovations, particularly with regard to the situation of SMEs. We will briefly explain the methodology of a qualitative interview survey (Görlach and Zvezdov, 2010) among intermediaries and SMEs – conducted as part of an overarching research project – in order to help us to further elaborate the policy mix. We will then bring forward the proposed policy mix - consisting of government funding schemes, innovation agents and innovation labs.

Measuring Resource Efficiency

Resource efficiency is a concept that relates an independent (input) to a dependent (output) variable. With regard to inputs, one usually examines the efficiency of resource utilisation either with regard to their monetary values or with regard to environmental indicators (which can also comprise measures of input-dependent emissions). With regard to outputs one can evaluate the efficiency of resource utilisation with regard to economic profit (exchange value) or the service produced (utility value). For example, in their evaluation of automobile producers' resource efficiency Hahn et al. (2009) take operating profit as the dependent variable, i.e. *output*. In contrast, the MIPS (Material Input Per Service Unit) (Schmidt-Bleek, 1993; Hertwich et al.,

1997; Spangenberg et al., 1999; Ritthoff et al., 2002; Schmidt-Bleek, 2009; Lettenmeier et al., 2009) method takes service units as dependent variables, i.e. *outputs*.

While calculating the efficiency of resource use by relating the monetary values of resource inputs to economic profit is relatively straight-forward, calculating the environmental stress associated with inputs and the services produced is less so. Giljum et al. (2011) have analysed the current state of the art of in the field of ecological resource use indicators: Different methodologies have been developed for accounting for different categories of inputs to production and consumption processes. The five basic categories of natural resources comprise: biotic and abiotic materials, energy, air, water and land area. There are a variety of indicators that take these five main categories of resource inputs differently into account. On the whole, employing different indicators in complementary ways seems preferable over focusing on just one.

Although they are clearly related, the ecological perspective on resource use, and thus resource efficiency, is not congruent with a business perspective. The major reason is that the prices of energy and materials don't reflect the "ecological costs" of resource and energy utilization (Costanza and Folke, 1997). Clearly, for business it is important to be able to relate the resource use of products and organisations to monetary values (Giljum et al., 2011). However, from the perspectives of corporate social responsibility and environmental regulation it is interesting to be able to relate ecological to monetary costs (Orbach and Liedtke, 2002; Busch et al., 2005; Busch et al. 2006).

The concept of macroeconomic resource productivity is particularly salient in sustainability discourse at the governmental level. There can be different approaches to calculating resource productivity. In Germany resource productivity is calculated as follows: Based on data from the macroeconomic material account the utilised domestically extracted abiotic resources and imported abiotic resources and goods measured in physical units are related to economic performance in terms of GDP (German Federal Statistical Office, 2012). As higher income countries tend to perform better in terms of resource productivity and resource consumption, in turn, is largely determined by income, from an ecological perspective it seems desirable that resource efficiency strategies be accompanied by a direct emphasis on resource inputs and emissions in order to promote *absolute* reductions (Bringezu and Bleischwitz, 2009; Steinberger and Krausmann, 2011).

The Benefits of Resource Efficiency

There are a variety of reasons that make the pursuit of resource efficiency a compelling policy objective (Görlach et al., 2009):

- **Resource efficiency for reasons of absolute resource scarcity**

  The need for an efficient utilization of certain resources arises from their geological and biochemical finiteness, which will eventually find its expression in their market prices.

- **Resource efficiency for micro-economic reasons**

  Material costs comprise a major share of the total costs of manufacturing industry. In 2007 material costs accounted for 46% of overall costs in the German manufacturing industry, while labour costs accounted only for 18% (Wied and Brüggemann, 2009). Increases in resource efficiency can help to raise factor productivity and enhance competitiveness by reducing costs. The efficient utilization of resources can be decisive for a business' competitiveness (Baron et al., 2005; Liedtke, 2005; Rennings et al., 2008). Although one might consider that the competitive pressures of a globalised economy would force companies to realise relevant efficiency potentials anyway, empirical evidence suggests that – for SMEs in particular – this often doesn't hold true (Schwegler and Schmidt, 2008).

- **Resource efficiency for macro-economic reasons**

  Often resources can only be found to a limited extent on a state's territory, making imports necessary. In this case a more efficient use of resources can positively affect the trade balance and help make the economy more resilient to external shocks by alleviating the impact of fluctuations in commodity prices (Bleischwitz et al., 2009c).

- **Resource efficiency as a contribution against climate change and for general environmental reasons**

  The energy consumption involved in resource extraction, refinement, transport, utilization and disposal contributes significantly to the emission of green house gases and other undesirable environmental effects (see Bringezu and Bleischwitz, 2009; Rockström, 2010;

UNEP, 2011a; UNEP, 2011b; European Commission, 2010; European Commission, 2011).

Although increasing resource efficiency in processes can - *ceterus paribus* - help to alleviate the strain on the earth's resources, due to the rebound effect, often a part of the savings from more resource efficiency is taken back by increased utilization, sometimes even to the point where one reaches a situation known as the *Jevons paradox*, where the actual resource savings are negative (Binswanger, 2001; Polimeni, 2009; Meyer, 2009). As increases in resource efficiency spur economic growth, and thereby resource demand, savings in resource efficiency can also be outdone by growth-induced overall consumption increases.

However, resource efficiency can be deemed an important prerequisite for making the reduction of resource consumption more attractive to important constituencies and for eventually decoupling welfare development from material throughput (Schmidt-Bleek 1993; Weizsäcker et al., 1997; Daly, 2004; Jackson, 2009).

In the following we shall concentrate on how innovation policy can contribute to raising resource efficiency, focusing on the case of Germany.

The Role of Resource Efficiency in Industrial Policy

When it comes to cost saving firms often look at labour rather than resources. In the economically-oriented debate, the relatively complex topic of resource and material efficiency receives much less publicity than labour costs (Baron et al., 2005). While labour costs are a classical object of the economist's calculus and stock markets often respond to lay-off decisions (Palmon et al., 1997), questions of resource and material efficiency need to be addressed cooperatively across the boundaries of disciplines and stages in the value chain: product and services design, material qualities, ecological effects and market conditions are ideally assessed in a holistic framework.

In the sustainability-oriented debate, the topic is rather prominent but its effects are differentially distributed: While eco-efficiency has become an important part of large corporations' response to societal criticism in the form of corporate social responsibility (CSR), SMEs are far less exposed to such criticism and thus have less pressure to cut down on resource consumption (Jenkins, 2009). From both perspectives, economies of scale can make it more appealing for larger firms to

optimise their eco-efficiency.

The importance of increasing resource efficiency is steadily becoming a more prominent topic of policy-making, both for environmental and economic reasons. Proposals for German industrial policy to be geared towards the fostering of resource and environment friendly innovations can be traced back at least to the year 1975 (Hauff and Scharpf, 1975; Jänicke and Lindemann, 2010: 127). Since then, case studies on environmental "green" innovations have shown that environmental policy instruments and actor specific incentives can play an important role in the creation of such innovations (Klemmer et al., 1999). However, until recently questions of innovations and environmental sustainability were usually subject to separate policy regimes. More recently, researchers within academia and governmental institutions have begun to bring these regimes closer together, at least conceptually (Fischer and Schot, 1993; Foxon and Pearson, 2008; Grübler et al., 2002; Hemmelskamp et al., 2000).

The concept of innovation policy comprises nearly all government measures that are intended to influence an economy's innovation activities towards a politically desired direction, ranging from the setting of framework conditions to targeted support programs (Bleischwitz et al., 2009b).

It has by now become clear that it is important to not only focus on incremental process innovations but that service and product innovations also need to move more to the centre of attention. Particularly systemic innovations, that include entire value nets and are more radical in character, are moving to the spotlight of analysis (Machiba, 2010; Bleischwitz et al., 2009b:71; European Commission, 2008; European Commission, 2009b).

Innovation and Resource Efficiency Policy in Germany

Innovation policy

Germany's innovation policy is marked by its multi-level character with the European Union, the federal state, Länder (states) and municipalities all playing their role. Although the European and sub-national levels have increasingly gained in importance in innovation policy since the 1980s the federal level has so far remained the most important, mainly due to the weight of its financial resources. Government support for R&D in Germany differs from many other comparable international examples by so far refraining from the use of tax breaks (Fier et al., 2009).

The high tech strategy of the German federal government has led to the introduction of a number of new research and innovation policy instruments in recent years. Among these are the Top Cluster Contest ("Spitzenclusterwettbewerb"), innovation alliances and other financial incentives for research, like government contributions to research and development efforts (Licht et al., 2009).

Resource policy

Germany has adopted an 'ecological industrial policy' that calls for a 'third industrial revolution' to be achieved by improving energy and resource efficiency as well as increasing the use of renewable raw material (German Federal Environment Ministry, 2008ab).

In 2002 the German federal government, within the framework of its sustainability strategy, decided to aim at doubling the energy and resource productivity until 2020, compared to 1994 levels (German Federal Government, 2002). Between 1994 and 2010 resource productivity rose by 47,5%. While material inputs decreased by 17,1%, GDP rose by 22,3%. Although the indicators is moving into the desired direction, the speed of the increases in resource productivity between 2006-2011 would only suffice to achieve 82% of the target value. Further complicating the picture is the fact that the increases in resource productivity can be mainly attributed to decreases in the utilisation of building materials (German Federal Statistical Office, 2012).

A recent conference on basic materials by the Federal Association of the German Industry and the instalment of a government agency dedicated to coordinating concerted approaches for securing their supply also highlight the raised profile of the resource *problematique* more generally (Evers, 2010; Mihm, 2010).

The German federal government has pursued the integration of the topic of resource efficiency in innovation policy measures for a few years by now (German Federal Environment Ministry, 2008ab).

Despite such promising approaches, however, resource efficiency gains in German companies have so far remained far from optimal. Many of the barriers to more resource efficient innovations still remain (Baron et al., 2005).

The Innovation Process and its Phases

Innovations have a process character and can be divided in different phases. Innovation impulses emanate from new technologies, in the form of a *technology push*, or from societal and economic actors that want to satisfy new needs or desires, in the form of a *demand-pull*[1]. While technology push factors seem to have a greater impact at the beginning of a product cycle, demand-pull factors exert their effect particularly in later phases of the product cycle (Coombs et al., 1987; Herstatt and Lettl, 2004). With regard to increases in a company's resource efficiency, the early phases of the innovation process are of particular importance (Pfriem et al., 2006). In these phases important decision are taken on what innovation projects are initiated, how the further trajectory of the process is shaped and how many resource are utilized over the span of the product life, with important consequences for the eventual product characteristics, production processes and the resulting costs structures (Herstatt, 2007). Here, current and future resource production and consumption patterns are often determined and business strategies are derived from, with a considerable effect on the configuration of the lead markets of the future.

Barriers to Innovation Processes in SMEs

Although SMEs have some advantages compared to bigger firms in terms of flat hierarchies, informal communication and fast decision making procedures, they also encounter manifold disadvantages in their innovation management: They only have limited capacities with regard to technology, finances and human resources and they don't have the resources to organize all parts of the firm as professionally as larger companies can do. Formal structures, e.g. a dedicated R&D department are often missing. Technical know how is usually generated and transmitted *within* departments concerned with production, construction or development or externally acquired via relations with customers or suppliers. Due to their inability to internalise all elements of the innovation process, SME innovation activities can depend crucially on well-functioning innovation networks or otherwise beneficial innovation environments (Dosi, 1988; Maillat, 1990; Freel, 2005; Bos-Brouwers, 2010). SMEs also often find it difficult to recruit qualified staff (KfW Banking Group, 2007).

[1] Many innovations are not planned but rather products of incremental change and many discoveries and inventions just happen by chance (Ayres and Warr, 2009). As these are dependent on previous technology use, they can still be subsumed under the concept of technology push.

Explicit knowledge, tacit knowledge and financial resources are essential actor-related factors for innovations processes (Murphy and Edwards, 2003; Fryges et al., 2007).

Explicit knowledge

A lack of explicit knowledge can be a central innovation barrier for SMEs (Fryges et al., 2007). According to the KfW Banking Group (KfW Banking Group, 2006) of all German SMEs who suffer from barriers in the unfolding of their innovation activities 19% do so from the lack of relevant market information and 13% from a lack of technological know how.

Tacit knowledge and innovation culture

The tacit knowledge of experienced business professionals can contribute significantly to the success of young innovations-oriented SMEs (Koskinen and Vanharanta, 2002; Fryges et al., 2007). According to the KfW Banking Group (KfW Banking Group, 2006) of all German SMEs who suffer from barriers in the unfolding of their innovation activities 31% do so from insufficient human resources and 20% from organizational problems.

Tacit knowledge is a key component of an innovative company culture. Financial and technical risks pose a particular high barrier when innovations are targeted at the entire apparatus of production or when they are systemic innovations that go beyond linear developments or product innovations by positing structural or systemic transformations. When the culture within a firm is too risk averse, staff will tend to shy away from innovations. Innovation management within a firm does not only determine what type of innovation a firm wants to bring to market within a specific time frame but also what means are employed to reach these aims. Even the best strategy and the most elaborated process planning can be insufficient when restrictive organizational structures and a poorly developed innovation culture inhibit the success of innovation management (Kienbaum Management Consultants, 2008).

Many SMEs only rely on a few select employees for their formal innovation activities. Integrating more employees in innovative activities by creating a more cooperative and innovative culture within a firm allows lifting the innovative resources of a wider array of employees. But the necessary intra-firm competencies for this are scarce in Germany (Kriegesmann and Kerka, 2007; Rohn et al., 2010).

Financial resources

During the phase of market introduction of innovations a lack of finance often leaves SMEs innovations in the dreaded *valley of death* (Murphy and Edwards, 2003). According to the KfW Banking Group (KfW Banking Group, 2006) of all German SMEs who suffer from barriers in the unfolding of their innovation activities 62% do so from a lack of financing opportunities.
Lack of capital is cited as one of the most salient barriers for SME's innovation activities (KfW Banking Group, 2007; Rennings et al., 2008; Hertin et al., 2008). Particularly newly founded SMEs often lack the capital resources for a sufficient investment in R&D activities. External financing is difficult as R&D projects combine high capital requirements with high risk - a combination often unattractive for banks, even more so with regard to smaller firms with lesser reporting obligations (Bornemann, 2001). Usually only relatively advanced projects offer a sufficient relation of chances and risks to make them attractive for private investments. For this reason often innovations from basic research are only hesitantly taken up by industry, leading to innovation gaps (European Commission, 2009a; Rennings, 1999). The gap in the transition from public to private financing of basic research activities aggravates this problem: the end of public funding often hits companies at the beginning of the phase dedicated to achieving a marketable product design - a phase that is marked by the need to raise more capital than usually (see Murphy and Edwards, 2003). Also, following the stricter credit rating procedure of Basel II and the global financial and economic crisis that began in 2007 many banks have withdrawn from SME financing and many of the remaining bank loans have become more expensive. The historically relatively small equity-to-assets ratio of German SMEs also means that loans have become increasingly unaffordable for them. However, bank loans remain the most important capital source for companies.

Barriers to Resource Efficiency Improvements in SMEs

The topic of resource efficiency has so far tended to be of rather negligible importance within most companies (Görlach, et al., 2009). The following barriers have been identified:

- **Lack of explicit and tacit knowledge**

  Successful resource efficiency strategies and innovation processes depend on well-qualified

managers and employees. However, the necessary expertise is often lacking. A lack of market information, an insufficient innovation culture within the company and a lack of clearly assigned responsibilities for the innovation process often add to this (KfW Banking Group, 2007; Rammer and Weißenfeld, 2008; Jänicke and Lindemann, 2010: 128).

- **Lack of financial resources**

  External barriers comprise problems with raising money from capital markets and insufficient target group specific government support funding portfolios (KfW Banking Group, 2007; Rammer and Weißenfeld, 2008).

Elaboration of Resource Efficiency Innovation Policies

In the following we elaborate a number of interlocking policy measures - part of a potential 'smart regulation' policy mix (Bleischwitz, 2010; Jänicke and Lindemann, 2010) - that are designed to lower barriers and provide strong incentives for innovations in resource efficiency. In focusing on such a 'smart regulation' policy mix, we follow the widespread agreement in the policy literature that environmental policy should intelligently combine different instruments instead of relying on a single 'super instrument' (Foxon and Pearson, 2008; Jänicke and Lindemann, 2010).

The scope of the policy mix is clearly limited and it would ideally complement – not compete with – other much-needed reforms, in particular those concerning ecological taxation (Ekins and Speck, 2011), Eco-Design (Siderius and Nakagami, 2013) and financial market reform (Onischka, Liedtke and Jordan, 2012).

In the development of the policy mix, it was important to us to take into account three observations that two of us have made many times in transdisciplinary research projects where SMEs were involved as practice partners:

1. SMEs often suffer from a lack of resources necessary for applying to innovative funding programs as well as for their implementation.

2. SMEs often lack a professional innovation management that can systematically prepare, implement and evaluate innovation projects.

3. SMEs often complained that innovation support funding programs were often *ad hoc* and sub-optimal in character.

In addition, we found it reasonable to assume that if innovation support funding programs

exhibited a greater emphasis on resource efficiency they would automatically generate more resource efficiency awareness among companies.

Based on these observations and our assumption, together with our project partners we developed a topic guide for a qualitative survey[2] (Görlach and Zvezdov, 2010) in order to generate insights for a policy mix that supports SMEs in engaging in resource efficiency innovation activities while taking into account their current difficulties in making use of already existing offers.

Survey Methodology

The aim of the interviews was to collect practical examples in order to expand the knowledge gained by previous research and theory building, to scrutinize it in the light of the findings, and to receive new input for further research. The interviews were conducted with experts from industries where resource efficiency is a particularly relevant issue and with intermediaries that are already acquainted with issues of resource efficiency. The survey was not intended to deliver representative results on barriers and incentives. Instead, it was pragmatically focusing on generating insights that could help us in the further elaboration of company related policy measures for increasing resource efficiency. Therefore, it was intended to conduct a systematizing qualitative interview survey of the specific barriers that block concrete steps towards more resource efficiency.

Survey method

The interviewers employed the survey method of the semi-standardized *systematizing* expert interview (Bogner and Menz, 2009). They aimed at "normalizing" and "everydaying" the situation in order to make it as closely as possible resemble the typical conversation among experts and at the same time facilitate an open and unrestricted expression of opinion (Pfadenhauer, 2009; Trinczek, 2009).

Topic guide

[2] In presenting the results of the survey, we may at times directly translate passages from our project partners' original research paper (Görlach and Zvezdov, 2010).

The respondents were asked questions on the importance of innovations, particularly with regard to resource efficiency, on barriers to innovation, conditions conducive to innovation and the (potential) role of specific instruments like government funding schemes, innovation labs and innovation agents.
The interviews were mainly conducted in Summer 2009, mostly face to face and sometimes by telephone, lasting for about 60 to 120 minutes each.

Sampling

For the sampling it was decided to purposively select both respondents that have an external view on the instruments as well as respondents that have an internal view on them. E.g. in the case of questions on resource efficiency consultations not only companies and intermediary organizations were interviewed but also consultants themselves.
For the level of intermediaries interviews were conducted with people from 15 different organizations and companies. These included consultancies, trade associations, educational institutions, financial services firms, and accounting firms. Intermediaries with an affinity to environmental issues and resource efficiency were given preference in the selection process. A detailed account of the distribution of interviewees working as intermediaries is provided in table 1.
For the level of the company interviews with staff from 11 companies of different sizes from the metal and plastics industries were conducted because these sectors are considered to have particularly high resource saving potentials (Baron et al., 2005). Preferential consideration was given to companies that had already collected experiences with questions of resource efficiency. Table 2 shows how interviewees were distributed over industries and firm sizes.

Survey data aggregation and analysis

The journaling of the interviews was done in two steps: During the interviews field notes where taken manually. Directly after the interviews information from the interviews was recorded in a computer file according to different topics, not chronologically. Towards the end of the interview phase all information was synoptically aggregated according to topics and to the different possible types of interviewee categories.

Survey results

In the following we present the survey results with respect to temporal prerequisites of well-functioning structures, the importance of government funding, the coherence of government funding, its take-up by companies and the problems they encounter in accessing it.

Temporal prerequisites

Both groups:

- Short-term structures were criticized as failing to support the sustained promotion of topics. A majority said that continuity of the programs would be a prerequisite for a sustained change of attitudes and behavioural patterns.

Intermediaries:

- Although the programs should be long-term, individual projects are often more interesting for companies when they are short, small and flexible.

Companies:

- Long-term programs or institutions that have been focusing for a long time on resource efficiency enjoyed a particularly good reputation among the surveyed companies.

Government funding is not decisive for final decision-making but important for awareness-raising

Both groups:

- Innovation support programs are not decisive for whether or not companies embark on an innovation project. Many also stated that the same holds for financing conditions.

Intermediaries:

- While government funding is not decisive for innovative activities, informed companies do take advantage of it.
- Nearly all respondents emphasized that state funding support programs serve as door openers for the resource efficiency discourse.

Companies:

- The surveyed companies normally gather information on funding opportunities *after* the planning but *before* the implementation. That means that the implementation is already decided before applications to funding schemes are considered.

More coherence and issue integration necessary

Intermediaries:

- Nearly all respondents complained that the highly differentiated character of the funding structure across different levels and ministries in Germany and the correspondingly high distribution of responsibility is a central barrier to company participation in the funding programs because it raises the costs of information acquisition considerably.
- It was criticized that funding is flowing predominantly for climate and energy projects and that resource efficiency is comparatively neglected.
- Respondents warned of an inflation of funding opportunities, saying that it is more important that extant programs are being fully utilized rather than creating new programs.

Companies:

- The topic of energy efficiency enjoys more salience than resource efficiency.

Insufficient take-up

Both groups:

- Extant state funding opportunities are not exhaustively utilized.
- When companies *are* aware of funding opportunities, they are also likely to make use of them.

Intermediaries:

- Lack of knowledge about funding programs.
- Funded projects are often not aligned with business reality.
- Funds tend to go more into pockets of research institutions rather than to companies directly.
- Conditional cash disbursements or vouchers are preferred over loans.

Companies:

- Most funding programs were known.
- Most companies were satisfied with funding programs, however smaller companies complained that they often don't belong to the program's target group.

Relatively high costs of and thresholds for applying for funding programs

Intermediaries:

- Time- and labour intensive procedures and bureaucratic structures can hinder take-up. Often consultants lead companies through bureaucratic procedures.

Companies:

- Despite support by third parties, applications for funding are associated with high administrative burdens, particularly for smaller companies.
- The collection and disclosure of sensitive documents and information was the most-mentioned barrier to applying for funding.

Elements of a Smart Regulation Policy Mix

Altogether we could identify five major barriers to resource efficiency innovations in SMEs based on prior literature reviews, our own experiences and the interviews:

- Lack of innovation culture within firms
- Lack of cooperation between firms situated along a value chain
- Lack of finance
- Lack of awareness
- Insufficient uptake of government funds

We now propose measures to systematically enable and foster resource efficiency innovations within small and medium sized enterprises (SMEs).

In searching for appropriate measures, here we focused on instruments that are directly targeted at stimulating companies to increase their own resource efficiency or those of the value chains they are embedded in. In a first step we gathered a number of possible instruments, differentiated according to where they aim to intervene along the different phases of the innovation process (invention, market introduction, diffusion) (Rennings, 2000). We then went on to define several

characteristics of the instruments: aims and target groups, effects on innovation activity and market processes, the mechanisms that are supposed to bring about the intended impacts, how existing barriers are addressed, empirical evidence so far, potentials and possibilities for further development of the instruments. The instruments were assigned a score between -3 and +3 on an ordinal scale for each of eleven subcategories that covered a) ecological effects, b) economic effects and c) political feasibility. This process allowed to condense prior research into a form that can be evaluated by external experts. While being a valuable exercise, the final selection of the instrument mix was not exclusively based on the score values but also on potential interaction effects with other instruments[3].

As a result of this process, we argue that in the area of resource efficiency related innovation and market entry SMEs can highly benefit from suitable funding support schemes and a professional consultation infrastructure consisting of innovation agents - both innovation assistants and business angels. Additionally, R&D cooperation among companies in the form of innovation labs can help to foster the emergence and growth of creative milieus and can help to overcome barriers to innovation within and among companies (Görlach et al., 2009).

Resource efficiency government funding schemes

Government funding of R&D can be a very effective instrument (Bruijn and Norberg-Bohm, 2005). By not determining in advance the supported projects but by setting incentives via funding guidelines it can be used to steer firm behaviour softly and indirectly. Sponsoring by funding programs can also represent gains in prestige and credibility for SMEs and can thereby be used as an instrument of symbolic reward (Clausen and Trettin, 2003).

We recommend promoting the idea of resource efficiency and the corresponding government funding support programs in a target group oriented way by creating intermediary resource efficiency structures comprising trade associations, consultancies and network activities and to integrate extant programs in a synergistic and coherent manner.

We recommend reducing the complexity of funding programs so that they become more appealing to SMEs. However, there is also a trade-off between two competing priorities: While it is desirable to fully disburse the funds and allow a great number of firms to participate it should

[3] A detailed account of the selection process can be found in Görlach et al. (2009).

also be an aim to prevent dead weight effects. Therefore, reporting requirements cannot be lowered too much.

In order to bring coherence to funding activities, the use of meta-projects is advisable. These meta-projects should have a mid term time horizon and connect smaller individual projects with each other and work on the further developments of the insights generated from the individual projects in order to later feed them back into the participating companies. The use of such meta-projects is of particular relevance with a view to promoting 'radical' environmental innovations that span entire value chains and are initially remote from the market (Jänicke and Lindemann, 2010: 130).

Most intermediaries mentioned the constraints that contract manufacturers are subjected to. Because they are highly focused on complying with customer requirements, resource efficiency aspects are neglected. However, only innovations across the entire value chain permit the development of systemic innovations (leapfrogging) (Schmidt-Bleek, 1993, 2008; Seiler-Hausmann et al., 2005; Seliger et al., 2007; Reid and Miedzinski, 2008; Bleischwitz et al., 2009b). Therefore, one could consider introducing a bonus that would be stepwise disbursed along the value chain. Such an integration of innovations along the value chain could be ideally situated in innovation labs.

An increase in resource efficiency cannot only be achieved by specifically resource oriented funding programs but also by including incentives for resource efficiency in programs with a more general and technology neutral outlook.

Innovation agents: business angels and innovation assistants

Because SMEs often don't have sufficient knowledge for successfully managing innovation oriented cooperation processes, external consultation can be pivotal. In order to fill the resource efficiency relevant knowledge gaps in firms it needs actors who can professionally and/or financially accompany innovation processes from invention to market introduction. We identified two types of such innovation agents with a particularly high synergistic potential: business angels and innovation assistants.

An alternative to the bank loans predominant in Germany could consist in venture capital. However, venture capital funds often only start to consider projects of a rather high volume. In the following we will thus particularly focus on the role of informal equity capital markets

(business angels). Business angels are capitalists that invest a share of their private monetary assets directly in companies. They help with funding firms when the risk is too high for banks and the need for capital is too insignificant for venture capital funds. They also often let them partake of their business experience and contacts. Particularly young technology-oriented firms whose founders have an engineering or science background can benefit from such additional business expertise (Fryges et al., 2007).

In comparison to the industrialized English-speaking countries the informal equity capital market in Germany is only poorly developed. Among business angels there is also only relatively little awareness that resource efficiency can be a relevant factor for competitiveness. This should not astonish as companies themselves also usually underestimate the economic potentials of resource efficiency (Rennings et al., 2008).

By granting particular tax breaks when business angels invest in resource efficiency innovations one can set additional incentives for such investments. A similar, though broader, instrument is being employed in Great Britain, the Enterprise Investment Scheme (EIS), and is having significantly positive effects on the financial volume of business angel activity (Boyns et al., 2003). Integrated support for informal and formal equity capital markets can create synergies. Business angels can leverage expertise and trust from the company in order to establish contacts to venture capital funds and banks.

Innovation assistants could be university graduates whose employment in firms as well as their special formation is at least partly state-funded. During their special formation they develop expertise on creating an innovative culture and managing innovations, cooperation and funding opportunities. A special component of their formation could focus on resource efficiency innovations. Such expertise could help to enrich the 'bounded rationality' of firms with an awareness of resource efficiency potentials (Simon, 1991).

In some German states there are already programs dedicated to the education and provision of such innovation assistants. The Austrian federal state Upper Austria also has made positive experiences with the Technology and Information Management (TIM) funding program where companies were actively and systematically approached by employees of the funding body with the aim of coaching them with innovation and cooperation projects. While it is not primarily a financial funding program, it does from time to time dispense grants to finance feasibility studies or a day of free coaching by TIM experts. Due to these measures firms can see, with only minimal initial risks involved, whether a research institution would be able to solve their

problems. Participating companies expressed their satisfaction about the consultant's good overview of the research scene and their coaching skills in cooperation projects (Sheik and Radauer, 2002). Such a model could be of considerable help in promoting the uptake of R&D government funding and in reducing the innovation related information deficits of SMEs. This is a good example of how support for innovation agents can make government-funding schemes far more effective.

We recommend offering postgraduate courses where young engineers and scientist can gain expertise on the social, economic and managerial aspects of eco-efficiency innovation management as well as on funding opportunities. Their employment within companies should then be partly subsidized for a limited period by regional or federal agencies.

Synergies can be achieved when innovation assistants help firms to get into touch with business angels, while business angels can pass on some of their knowledge to innovation assistants.

Innovation labs

In order to increase the resource competency and the corresponding ability to innovate in companies it is important to facilitate opportunities for cooperation that are flexible with regard to their organizational and infrastructural features. Joint innovation labs can have the potential to directly address the needs of innovation oriented SMEs by fostering focused collaboration with partners from research institutions and other business, the emergence and growth of creative milieus as well as the pooling of resources and the distribution of risks. In this way, SMEs can make up for the disadvantages of their comparatively small sizes. This can be very beneficial, for while intermediaries tended to perceive of innovations as the core business of every company, the majority of the surveyed companies themselves didn't assign a central role to innovations. Instead they saw innovations as belonging to the portfolio of bigger companies, because for SMEs the costs of innovations would often outweigh their benefits. Thus, cooperation can be particularly important for SMEs that don't enjoy sufficient resources for appropriating the entire knowledge necessary for complex innovations.

It is important to create innovation laboratories specifically geared towards the needs of SMEs. Innovation agents can be very helpful in facilitating this. As firms value their business secrets highly (Horbach et al., 2003) it can also contribute to the success of innovation labs when the resulting barriers to cooperation are managed by experienced and neutral coaching.

The integration of business angel networks (BANs) with innovation labs and the availability of resource efficiency related tax breaks wields the potential for aiding in the emergence of BANs specialized in attaining and investing in resource efficiency gains. Innovation labs should be constructed in a way that taps into the potentials of the aforementioned measures:

1. Alignment to meta-projects that aim at realizing the resource efficiency potential along the value chain, including that of contractor suppliers. Here trust and mutually compatible interests can be expected to be bigger than among direct competitors.
2. Participation of innovation assistants that know how to manage the network activities in an innovation lab.
3. Inclusion of business angel networks (BAN) whose investment incentives are heightened by tax breaks for resource efficiency investments.
4. Stepwise disbursement of resource efficiency bonuses along the value chain.

The benefits of combining the three instruments

The integration of tax breaks for investments in resource efficiency, the cooperation of business angel networks (BANs) with innovation labs, the introduction of innovation assistants and a higher emphasis on resource efficiency in government funding schemes have the potential to interlock in such a way as to synergistically address all five of the aforementioned barriers: (B1) lack of innovation culture within firms, (B2) lack of cooperation between firms situated along a value chain, (B3) lack of finance, (B4) lack of awareness, (B5) insufficient uptake of government funds.

Resource efficiency government funding schemes

While funding schemes foremost support companies financially in their resource efficiency endeavours (response to B3), their effects can be more far-reaching: The introduction of meta-projects to resource efficiency government funding schemes can connect smaller individual projects and thereby link the participating companies with each other. The Step-wise disbursement of a bonus along the value-chain provides additional incentives for this (responses to B2). Tax breaks can make investments more attractive for business angels (response to B3). Results from meta-projects are fed back into participating companies (response to B1). The

inclusion of incentives for resource efficiency in programs with a more general and technology neutral outlook increases resource efficiency awareness (response to B4).

Business angels

Business angels can help with funding, out of their own pockets as well a by facilitating access to venture capital (response to B3). Due to their contacts they can also facilitate networking activities among companies (response to B2). Ideally, they also pass on some of their knowledge to the companies they invest in (response to B1). The integration of business angel networks (BANs) with innovation labs and the availability of resource efficiency related tax breaks also wields the potential for aiding in the emergence of BANs specialized in attaining and investing in resource efficiency gains.

Innovation assistants

Innovation assistants can contribute towards the creation of an innovative culture (response to B1), drive forward cooperation (response to B2), tap into government funding schemes (response to B5) and get in touch with business angels (responses to B3). They can also support innovation labs by navigating the problems that can arise from opening up the knowledge silos of individual companies, e.g. with respect to trade secrets and intellectual property rights.

Innovation labs

Innovation labs can facilitate inter-firm cooperation (response to B2) and can help to lift the innovation culture in firms (response to B1). They also provide a focal point for cooperation, innovation activities and BANs.

Situating the instruments within a broader framework

A standardized monitoring of government R&D programs like performed by the Austrian Institute of Technology facilitates evaluations, raises their quality and thereby has positive effects on the R&D programs in questions (Rhomberg et al., 2006). This model has the potential to be

successfully transferred not only to Germany but also to a host of other countries. Both the instruments of government funding schemes and tax breaks for investments in resource efficiency suffer from the potential dangers of additionally and windfall profits. Further research has to be conducted in order to minimize the potential for these to occur. A centralized evaluation agency could be charged with the continuous monitoring of these aspects.

Conclusion

We have analysed five major barriers to resource efficiency innovations in German SMEs, comprising deficits in innovation culture, inter-firm cooperation along the value chain, finance, awareness and take-up of government funds. We proposed a distinct policy mix as a response to this situation. The policy mix comprises the interlocking and synergistic elements of government funding schemes, innovation agents and innovation labs. We also recommended the creation of an independent evaluation agency for raising program quality and avoiding the dangers of windfall profits.

As a next step, additional representative surveys could contribute towards gaining a fuller picture of the empirical realities, as experienced by the staff of relevant companies and intermediaries, and to fine-tune resource efficiency measures and policies.

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Tables

Table 1: Distribution of interviewees working as intermediaries

	Associations	Resource efficiency consultants	Environmental education	Financial services	Financial auditing firm	Comprehensive cross-sectoral institutions	Total
Organisations	5	3	1	1	1	4	15
Individuals	6	4	1	1	1	8	21

Sometimes more than one individual per intermediary organisation was interviewed.

Adapted from: Görlach and Zvezdvov (2010)

Table 2: Distribution of interviewees working for companies

	Company size			Total
	Small	Medium	Large	
Metal industry				
Companies	3	3	2	8
Individuals	3	4	4	11
Plastics industry				
Companies	1	1	1	3
Individuals	1	1	2	4

Sometimes more than one individual per company was interviewed.

Adapted from: Görlach and Zvezdvov (2010)