Impact of financial and informational policies promoting energy efficiency in SMEs

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Keywords

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Abstract

In light of alleged un-tapped potentials for cost effective energy savings in the industrial sector various policies have been implemented to overcome barriers to the adoption of energy efficiency measures by companies. Especially, small and medium-sized companies (SMEs) are supported in their adoption decision by informational and financial instruments. To adequately design these instruments a thorough understanding about their mechanism is crucial. Thus, this paper investigates the impact of two financial instruments (funding for cross-cutting (CC) technologies, low-interest loan) in addition to an informational instrument (energy audit) on the adoption of four generic energy efficiency measures in SMEs in Germany. Based on 766 observations, we apply t-tests and propensity score matching techniques to estimate the effects of these instruments. Findings suggest that the financial instruments in addition to an energy audit accelerate the adoption, but effectiveness varies by technologies. Based on a t-test, the adoption rate for insulation is 15 % and for heating 19 % higher for companies which used a low-interest loan (and an energy audit) compared to companies which only had an energy audit. For lighting, the adoption rate is nearly 12 % higher for companies which used the CC technologies programme (and an energy audit) compared to the control group. The propensity score matching results differ: To adopt measures for insulation the propensity is 12 %, for heating optimization 12% and for heating about 25 % higher for companies which used a low-interest loan (and energy audit) compared to the control group. Regarding lighting we do not find a significant effect of the CC technologies programme on the adoption. Findings indicate that estimates of policy effectiveness by t-tests might be misleading, i.e. overestimating the effectiveness regarding the adoption of measures for lighting, insulation and heating optimization, and underestimating the effectiveness for heating.

Introduction

In light of the alleged un-tapped potential for cost effective energy savings in the industrial sector (e.g. Boßmann et al. 2012) which is, among other things, mainly inhibited by lack of information, capital (e.g. Schleich 2009, Schleich and Gruber 2008), principal-agent relationships and company absorptive capacity (Olsthoorn et al. 2017), policy makers try to overcome these barriers by establishing different policy instruments. For this purpose numerous policy instruments have been implemented, ranging from regulatory approaches such as mandatory energy audits (Hirzel et al. 2016), voluntary approaches such as agreements among others applied in Bulgaria, Finland, Netherlands and Switzerland (Nabitz et al. 2016), financial instruments such as funding programs for the adoption of cross-cutting or production technologies (BMWi 2016) as well as information instruments such as energy audits (Mai et al. 2014). To adequately design these instruments an understanding about their impact, mechanism and interdependency is crucial. Thus, the aim of this paper is to investigate the impact of two different financial instruments, in this case a funding for cross-cutting technologies as well as low interest loans in addition to an informational instrument, an energy audit, on the adoption of energy efficiency measures in small and medium sized enterprises (SMEs). For this purpose, we employ propensity score matching estimators to econometrically analyse the impact of the two different policy instruments separately.

In the literature so far only a few empirical analyses dealt with the impact of more than one policy instrument at once. The lack of empirical analyses may among others be caused by a lack of ex-post data across various instruments. The majority of these papers investigate the interaction of the European Emission Trading System (EU ETS) with other national instruments (e.g. Kautto et al. 2012, OECD 2011). Newell et al. (1999) find that price policies may only be effective in combination with other policies such as standards, labelling or information campaigns. Other research in the field of energy efficiency often analyses the impact of only one policy instrument, e.g. Fleiter et al. (2015) investigate the impact of the German energy audit program and find that firms adopt 1.7–2.9 more energy efficiency measures than without the program. Backlund and Thollander (2015) analysed the Swedish energy audit programme and find that firms adopted 53 % of the proposed energy efficiency measures.

Our approach differs from the existing literature in the following aspects: First, we analyse the impact of two different policy instruments in addition to an energy audit. Second, we apply propensity score matching techniques to estimate the average treatment effect (ATT) of the two policy instruments in addition to an energy audit on the adoption decision of four generic energy efficiency measures. From a methodological point of view this makes it possible to generalize our findings and thereby draw conclusions for future policy making. In addition, this statistical method allows us to compare the adoption rate of treated and non-treated companies with similar characteristics and therefore to control for confounding factors.

The paper is organised as follows: Section 2 explains the categorization and definition of instruments, their underlying mechanism as well as the current policy background in Germany. Section 3 describes the data set used for the empirical analysis and presents the methodology applied by briefly explaining the Propensity Score Matching Technique. Section 4 presents the main results of the t-tests as well as the matching results. The final section summarizes our findings and concludes the paper.

Background

To overcome existing informational barriers energy audits are among others suitable concepts for companies to improve their knowledge about the energy consumption as well as about energy saving potential. Subsidies for energy audits are a common policy instrument to overcome market failure caused by imperfect information in energy technology and capital markets, a frequently cited barrier to EEM adoption in organizations (e.g. Schleich 2004, Anderson and Newell 2004, Thollander and Palm 2013, Olsthoorn et al. 2017). Current EU regulation, Article 8 of the Energy Efficiency Directive 2012/27, requires audits for large enterprises only and Member States must "encourage SMEs to undergo" them (EC 2012). Thus, German policy makers are fostering the implementation of energy audits in SMEs by a funding programme besides mandatory energy audits for large companies. Although energy audits have been found to be a suitable concept to increase industrial energy efficiency (Schleich et al. 2015), empirical results demonstrate that often only part of the recommendations are implemented (see for example Table 6 in Fleiter et al. 2012). In addition, access to capital and difficulties financing investments in energy efficiency has been identified as one of the most important barriers in literature (e.g. Schleich and Gruber 2008, Thollander and Palm 2013). This is the reason why policy makers established additional financial instruments to motivate companies to realise the recommended energy efficiency measures. Financial instruments can be divided into direct and indirect subsidies. *Indirect* incentives or taxes and charges either impose a fee on each unit of undesirable activity, i.e. on energy demand and/or direct related emissions, or are based on direct payments such as tax reductions, price supports or equivalent mechanisms (e.g. Gupta et al. 2007, Sprenger 2000). Our analysis focuses on two different *direct* financial instruments: This is firstly a funding programme for cross-cutting technologies by which since 2012 the German Federal Ministry for Economic Affairs and Energy supports SMEs for an investment in energy efficient cross-cutting technologies[1]. Secondly, some companies made use of a low-interest loan administered by KfW, the German Bank of Reconstruction. This loan is among others accessible for all investments concerning machinery and equipment in the field of energy efficiency. Companies may apply for both types of financial measures. Continuously monitoring and evaluating these instruments is expected to contribute to improve effectiveness and efficiency. For this purpose, our paper provides valuable empirical insights by studying the impact of financial policy instruments in addition to an informational intervention (energy audit).

Data and Methodology

DATA

We use data from a survey of companies in 2014 which voluntarily participated in the German SME Energy Consulting Program (called "Energieberatung Mittelstand") launched by the Federal Ministry for Economic Affairs and Energy in 2008. This data has been generated during an evaluation of this programme by Mai et al. (2014). The program supports SMEs to conduct an energy audit and thereby to improve their knowledge on energy consumption as well as on energy saving potentials. For this purpose, it offers financial support for screening and detailed energy audits by qualified and independent consultants. Our original sample consists of 1,471 observations which all had an energy audit funded by this program. A sub-sample additionally used funding for cross-cutting technologies and/or low-interest loans for the implementation of subsequent energy efficiency measures. After removing missing values for our calculation our final sample consists of 766 observations. The distribution of variables in the final and original sample is rather similar. Table 1

1. Eligible technologies include, among others, electric motors and drives, pumps, HVAC systems, compressed air systems, heat recovery systems and waste heat recovery (only for air conditioning systems and compressed air systems) (BMWi 2016).

Table 1. Descriptive statistics and definitions of variables.

Variable	Definition	N	Mean (Std. Dev.)
lighting	Adoption of lighting measures (binary)	766	66.2 %
insulation	Adoption of insulation measures (binary)	766	29.2 %
heating	Adoption of heating measures (binary)	766	35.9 %
heatopt	Adoption of heating optimization measures (binary)	766	48.0 %
numempl	Number of employees	766	58 (57)
enercostshare	Energy cost share	766	7.7 % (12.9 %)
ems	1 if energy management system in place	183	23.9 %
	0 otherwise	583	76.1 %
environmgmt	1 if environmental management system in place	66	8.6 %
	0 otherwise	700	91.4 %
enermanager	1 if company has an energy manager	339	44.3 %
	0 otherwise	427	55.7 %
cc	1 if company used funding programme "cross-cutting technologies"	118	15.4 %
	0 otherwise	648	84.6 %
kfw	1 if company used KfW low-interest loan	132	17.2 %
	0 otherwise	634	82.8 %

summarizes the descriptive statistics for all variables in the data set. Most companies belong to metallurgy (20.7 %) and other energy intense production (20.0 %) followed by other services (13.8 %), other non-energy intense production (10.8 %), other trade (10.6 %), hospitality (10.2 %), food trade (8.8 %) as well as car sales (5.1 %).

In our sample, 95 companies made use of the funding from the cross- cutting technologies programme only, 81 made use of a loan only, 37 companies made use of both instruments, and 553 companies used neither of the two instruments.

METHODOLOGY

We analyse the effects of two different financial instruments in addition to an energy audit on the adoption of energy efficiency measures in four fairly generic energy efficiency technologies: (1) lighting, (2) thermal insulation of buildings, (3) exchange of heating system and (4) optimization of the heating system. To investigate the differences regarding the adoption of energy efficiency measures between the three groups

1. companies which only made use of an energy audit (*Group Audit only*),
2. companies which made use of an energy audit and of a funding provided by the program "cross-cutting technologies (*Group Audit & CC*) and
3. companies which made use of an energy audit and of a low-interest loan (*Group Audit & Loan*).

So, observations on companies which used both financing instruments are used twice, once in *Group Audit & CC* and in *Group Audit & Loan*. In a first step, we perform simple t-tests using the t.test function in R (R core team 2016) which allows for unequal variances. In a second step, relying on the Roy-Rubin potential outcome evaluation framework (Roy 1951, Rubin 1974), we employ non parametric propensity score matching algorithms to estimate the effects on the adoption of energy efficiency measures for companies which made use of one of the financial instruments in addition to an energy audit. In particular, we are interested in ATT (the average effect of treatment on the treated), i.e. the effect of the financial instrument in addition to an energy audit on those companies which made use of these programmes. Therefore, a binary treatment indicator, either *cc* or *kfw* equals 1 if a company used a financial instrument and zero otherwise. Since for each company only one of the potential outcomes can be observed which is also called the fundamental problem of causal inference, we employ ATT and estimate this effect by matching estimators. Thus, we rely on data of companies as a control group which only had an energy audit, but which show similar relevant characteristics as the Groups *Audit & CC* and *Audit & Loan*. In doing so, we assume "selection on observables" (sometimes also called "unconfoundedness" or "conditional independence assumption" (CIA)) based on the idea that we strive to make the treatment independent of the potential outcomes conditional on observed covariates. Thus, we assume that the treatment is conditionally independent of potential outcomes or in other words, differences in outcomes between observations in treated and control group with the same values for the covariates could be assigned to the treatment (see e.g. Imbens 2004).

Table 2. Results of two-sided t-test.

	Group	N	Adoption rate	Difference in percentage points	
Lighting	Audit only	553	65.3 %	11.8	**
	Audit & *CC*	118	77.1 %		
Insulation	Audit only	553	27.0 %	15.4	**
	Audit & *Loan*	132	42.4 %		
Heating	Audit only	553	30.6 %	19.4	***
	Audit & *Loan*	132	52.6 %		
Heating optimization	Audit only	553	44.0 %	12.8	**
	Audit & *Loan*	132	56.8 %		

**** significance level p< 0,1 %, **significance level p < 1 %.*

Results

RESULTS OF T-TESTS

We analyse the adoption of four generic energy efficiency measures which are common to all companies and typically explored in any energy audit. The adoption rate in our sample is defined as the share of companies which adopted one or more energy efficiency measures in the respective technological field. Both sub-groups of companies which conducted an energy audit and additionally used a low-interest KfW loan or a funding from the program "cross-cutting technologies" have a significant higher adoption rate compared to companies which only conducted an energy audit. The results of the t-tests regarding the adoption rate for the different cross-cutting technologies show similar results (see Table 2). The adoption rate for insulation is 15.4 percentage points higher for companies which made use of a low-interest loan (and had an energy audit) compared to companies which only had an energy audit. Similarly, the adoption rate for heating is 19.4 percentage points higher and for insulation 15.4 percentage points higher for these companies compared to companies which only had an energy audit. For lighting the cross-cutting technologies programme is eligible for funding. For this technology the adoption rate is 11.8 percentage points higher for companies which participated in this programme (and had an energy audit) compared to companies which only had an energy audit.

RESULTS OF PROPENSITY MATCHING

We use the *matchIT* package (Ho et al. 2011) of the R statistical software (R core team 2016) to estimate the matching estimators. Table 3 below presents the findings of the logit models underlying the propensity score matching estimators. The propensity to take a low interest loan is statistically significant for three of the sectors (coded by dummy variables): Food trade, other trade and other services. Neither the number of employees nor the presence of an energy or environmental management systems are significantly different from zero. The propensity to use the cc technology subsidy on the other hand, is positively and statistically significant related to the (log10 of) the number of employees and the presence of an environmental management. Furthermore, several of the sectors have a significant impact on the propensity to take cc technology subsidies. In sum, the findings are intuitive yet only a limited number of variables are significant.

Based on the underlying logit models shown in Table 3 in a subsequent step we calculate propensity score matching estimators. For the nearest neighbour matching (with one nearest neighbour) estimating the adoption of insulation, heating and heating optimization measures driven by the low-interest loan, the sample size consists of 132 matched observations whereas for the nearest neighbour matching estimating the adoption of lighting measures driven by the cc technologies subsidy 118 observations could be matched. In a third step, we use the package *mfx* (Fernihough 2015) of the R statistical software (R core team 2016) to estimate the marginal effects reflecting the ATT of our financial instruments.

Table 4 presents the results of the nearest neighbour matching estimation for the three technological areas insulation, heating and heating optimization which are all eligible for financial support by a low-interest loan. In addition, Table 5 presents the results for the example 'lighting' which is eligible for funding by the cc technologies programme.[2] The nearest neighbour matching estimates presented in Table 4 and Table 5 satisfy the *common support assumption*, i.e. to estimate the effects of the financial instruments only group observations with cc technologies subsidy (cc) or low-interest loan (kfw) are used where the propensity scores overlap with control group observation (for the means of covariates between the Groups Audit only and Audit & CC or Audit & Loan see TableAnnex 1 and TableAnnex 2).

The propensity to adopt measures for insulation is 12.1 percentage points higher for companies which made use of low-interest loan in addition to an energy audit compared to companies which only had an energy audit. Compared to the t-test results (without matching) with a difference of 15.4 percentage points this is substantially lower. However, when taking into account the confidence intervals the values are of a similar magnitude. For measures regarding heating optimization the picture is quite similar: The propensity to adopt measures in this area is 11.6 percentage points higher for companies which made use of a low-interest loan in addition to an energy audit than for companies which only had an energy audit. Also in this case the difference of the propensity

2. At the time of data collection lighting was eligible for funding in the cross-cutting technologies programme (BMWi 2014). However, since 29th April 2016 the replacement of lighting is not eligible any more (BMWi 2016).

Table 3. Logit estimates of taking low-interest loan and using CC technology subsidies.

	Low-interest loan		CC technologies subsidy	
Intercept	-0.746	***	-1.595	***
log10 Number of employees	-0.131		0.512	*
EMS yes	0.150		0.012	
Environmgmt yes	0.526		0.775	*
Energy manager yes	-0.147		-0.375	
Sector Metallurgy	-0.590		-0.905	*
Sector Cars sales	-0.524		-2.725	*
Sector Hospitality	-0.388		0.103	
Sector Other energy intense production	-0.474		-1.615	***
Sector Other non-energy intense production	-0.662		-1.029	*
Sector Food trade	-1.117	*	-1.141	*
Sector Other trade	-1.186	*	-0.323	
Sector Other services	-0.929	*	-0.787	
Observations	766		766	

**** significance level p<0,1 %, **significance level p <1 %, * significance level p<5 %, † significance level p<10 %.*

Table 4. Marginal effects at mean (MEM) for adopting measures in insulation, heating or heating optimisation.

	Insulation		Heating		Heating optimization	
Loan	0.121	*	0.249	***	0.116	†
log10 Number of employees	-0.068		0.033		0.020	
EMS yes	-0.000		-0.110		-0.001	
Sector Metallurgy	0.303	*	0.208		0.037	
Sector Cars sales	0.487	***	0.317	†	0.399	***
Sector Hospitality	0.285	†	0.332	*	0.303	**
Sector Other energy intense production	0.164		0.104		-0.018	
Sector Other non-energy intense prod.	0.298	†	0.101		-0.079	
Sector Food trade	0.030		-0.315	*	-0.165	
Sector Other trade	0.209		0.220		0.117	
Sector Other services	0.169		0.175		0.083	
Environmgmt yes	-0.018		0.368	***	0.038	
Enermanager yes	-0.012		-0.011		0.089	

**** significance level p<0,1 %, **significance level p<1 %, * significance level p<5 %, † significance level p<10 %.*

score matching is slightly lower than in the t-test (12.8 percentage points). The ATT for heating is even higher, estimated by about 25 percentage points for companies which made use of low-interest loan in addition to an energy audit (see Table 4[3]). Only in the case of heating the difference estimated by the matching technique is higher than in the t-test before which suggested a difference of 19.4 percentage points (see Table 2).

If we take a closer look at the replacement of lighting which is eligible for funding by the cross-cutting technologies programme, we do not find a significant effect of this programme (in addition to an energy audit) on the adoption of lighting technologies even though we the null hypothesis was rejected by the t-test in the first step (see Table 5[4], p-values in parenthesis).

Conclusions and policy implications

In this paper we analyzed the effects of providing funding for cross-cutting technologies or low-interest loans in addition to providing information via energy audits on the adoption of four generic energy efficiency measures.

Based on non-parametric matching analyses our findings suggest that both financial instruments in combination with

3. The results estimating MEM in Table 4 and Table 5 are similar to the results estimating average marginal effects (AME).

4. The results estimating MEM in Table 4 and Table 5 are similar to the results estimating average marginal effects (AME).

Table 5. Marginal effects at mean (MEM) for adopting measures in lighting (p-values in parenthesis).

	Lighting	
CC	0.089	(0.843)
log10 Number of employees	0.000	(0.998)
EMS yes	-0.038	(0.851)
Sector Metallurgy	-0.011	(0.921)
Sector Cars sales	0.228	*** (0.000)
Sector Hospitality	0.256	(0.863)
Sector Other energy intense production	-0.104	(0.825)
Sector Other non-energy intense production	-0.068	(0.841)
Sector Food trade	-0.022	(0.897)
Sector Other trade	0.069	(0.859)
Sector Other services	-0.025	(0.877)
Environmgmt yes	0.127	(0.864)
Enermanager yes	-0.011	(0.897)

**** significance level p<0,1 %.*

an energy audit accelerate the adoption of four generic energy efficiency measures in SMEs, but effectiveness varies by technologies. The propensity to adopt measures for insulation is 12.1 percentage points higher, for heating optimization 11.6 percentage points higher and for heating about 25 percentage points higher for companies which made use of a low-interest loan in addition to an energy audit compared to companies which only had an energy audit. Regarding lighting based on the propensity score matching technique we do not find a significant effect of the cross-cutting technologies programme (in addition to an energy audit) on the adoption of lighting technologies. Our findings suggest that estimates of policy effectiveness based on simple t-tests might be misleading, i.e. overestimating the effectiveness regarding the adoption of energy efficiency measures for lighting, insulation and heating optimization, and underestimating the effectiveness for heating.

With a view to the design of policy instruments our findings therefore suggest that additional financial policies in addition to an energy audit are effective in accelerating the adoption of the discussed energy efficient technologies. However, financial subsidies always come up with disadvantages and are disputed for a variety of reasons in the context of the cost-effectiveness. One of these problems are free-rider effects related to financial instruments which are likely to arise. Free-riders are defined as agents who make use of the subsidy, but would have undertaken the subsidised action anyway – and without any delay (Blok et al. 2004). Consequently, policy-makers should try to avoid these effects with an effective design of the policy instrument, including suitable requirements for eligibility of funding.

Further research is needed evaluating the interaction effect between the low-interest loan and the cross-cutting technologies funding programme. Due to the size of our sample, only 37 companies made use of both financial instruments, this has not been possible in this paper. For future investigations the question can be raised if instruments are overlapping, reinforcing or independent of each other to gain insights in their impact and mechanism by understanding their interdependency. Besides our approach could be further applied to a control group which includes companies which nor had an energy audit neither used any other additional policy instruments to clearly in comparison investigate the impact of the different policy instruments as well as to analyse potential free-rider effects.

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Annex[5]

TableAnnex 1. Means of covariates between loan treatment and control group before and after matching.

	Means Treatment Loan & Audit Group	Means Audit only Control Group	Mean Difference
Summary of balance for all data			
Distance	**0.189**	**0.169**	**0.020**
log10 Number of employees	**1.529**	**1.527**	**0.002**
Ems0	**0.712**	**0.771**	**-0.059**
Ems1	**0.288**	**0.229**	**0.059**
Environmgmt1	**0.128**	**0.077**	**0.052**
Enermanager1	**0.462**	**0.473**	**0.024**
Sector Metallurgy	**0.197**	**0.192**	**0.005**
Sector Cars sales	**0.053**	**0.047**	**0.006**
Sector Hospitality	**0.121**	**0.099**	**0.031**
Sector Other energy intense production	**0.000**	**0.180**	**0.040**
Sector Other non-energy intense production	**0.220**	**0.101**	**-0.003**
Sector Food trade	**0.053**	**0.088**	**-0.035**
Sector Other trade	**0.061**	**0.107**	**-0.047**
Sector 99 Other services	**0.106**	**0.134**	**-0.028**
Summary of balance for matched data			
Distance	**0.189**	**0.189**	**0.000**
log10 Number of employees	**1.529**	**1.483**	**0.046**
Ems0	**0.712**	**0.712**	**0.000**
Ems1	**0.288**	**0.288**	**0.000**
Environmgmt1	**0.128**	**0.144**	**-0.015**
Enermanager1	**0.462**	**0.477**	**-0.015**
Sector Metallurgy	**0.197**	**0.205**	**-0.008**
Sector Cars sales	**0.053**	**0.060**	**-0.008**
Sector Hospitality	**0.121**	**0.114**	**0.008**
Sector Other energy intense production	**0.000**	**0.242**	**-0.023**
Sector Other non-energy intense production	**0.220**	**0.099**	**0.000**
Sector Food trade	**0.053**	**0.053**	**0.000**
Sector Other trade	**0.061**	**0.046**	**0.015**
Sector Other services	**0.106**	**0.121**	**0.015**

5. All values are rounded.

TableAnnex 2. Means of covariates between CC treatment and control group before and after matching.

	Means Treatment CC & Audit Group	Means Audit only Control Group	Mean Difference
Summary of balance for all data			
Distance	**0.200**	**0.146**	**0.054**
log10 Number of employees	**1.576**	**1.519**	**0.058**
Ems0	**0.754**	**0.762**	**-0.008**
Ems1	**0.246**	**0.238**	**0.008**
Environmgmt1	**0.127**	**0.079**	**0.048**
Enermanager1	**0.398**	**0.451**	**-0.052**
Sector Metallurgy	**0.195**	**0.193**	**0.002**
Sector Cars sales	**0.009**	**0.056**	**-0.047**
Sector Hospitality	**0.170**	**0.082**	**0.088**
Sector Other energy intense production	**0.102**	**0.202**	**-0.101**
Sector Other non-energy intense production	**0.093**	**0.102**	**-0.009**
Sector Food trade	**0.059**	**0.086**	**-0.027**
Sector Other trade	**0.144**	**0.091**	**0.053**
Sector Other services	**0.127**	**0.130**	**-0.003**
Summary of balance for matched data			
Distance	**0.200**	**0.198**	**0.002**
log10 Number of employees	**1.576**	**1.541**	**0.034**
Ems0	**0.754**	**0.763**	**-0.009**
Ems1	**0.246**	**0.237**	**0.009**
Environmgmt1	**0.127**	**0.119**	**0.009**
Enermanager1	**0.398**	**0.424**	**0.025**
Sector Metallurgy	**0.195**	**0.195**	**0.000**
Sector Cars sales	**0.009**	**0.009**	**0.000**
Sector Hospitality	**0.170**	**0.220**	**-0.051**
Sector Other energy intense production	**0.102**	**0.102**	**0.000**
Sector Other non-energy intense production	**0.093**	**0.068**	**0.025**
Sector Food trade	**0.060**	**0.059**	**0.000**
Sector Other trade	**0.144**	**0.119**	**0.025**
Sector Other services	**0.127**	**0.144**	**-0.017**