Ilmenau University of Technology

Institute of Economics

Ilmenau Economics Discussion Papers, Vol. 19, No. 91

Rising Energy Prices and Advances in Renewable Energy Technologies

Sherief Emam & Thomas Grebel

July 2014

Institute of Economics

Ehrenbergstraße 29
Ernst-Abbe-Zentrum

D-98 684 Ilmenau

Phone 03677/69-4030/-4032
Fax 03677/69-4203

http://www.wirtschaft.tu-ilmenau.de

ISSN 0949-3859

Rising Energy Prices and Advances in Renewable Energy Technologies

Sherief Emam* Thomas Grebel

Abstract: In this paper we investigate the impact of rising energy prices on technological progress in the market for renewable energies. We use patent data of OECD countries from 1970 to 2010 and test the impact of oil prices on the innovative success of countries; R&D, investment activities, electricity consumption, etc. are used as control variables. We compare several models such as Pooled Mean Group (PMG), Mean Group (MG), Count data (CD) and Dynamic fixed effects (DFE) models to distinguish short and long-term effects. The preliminary results show that increasing energy prices seem to encourage innovation in renewable energy technologies.

Keywords: Renewable Energy, Heterogeneous Dynamic Panel Data, Technological Progress

JEL: Q55, C23

I. INTRODUCTION

THIS paper tries to provide evidence to the relationship between rising energy prices and technological progress in the market for renewable energies. The technology push and the demand pull approach, respectively, argue why we observe technological advances in industries. This still is an ongoing debate in the domain of evolutionary economics. The technology push argument claims that it is the advances in sciences that may induce the rate and direction of technological change in contrast to the demand pull approach which finds the drivers of technological

* Corresponding author: TU Ilmenau, Ehrenbergstr. 29, 98684 Ilmenau, Germany, e-mail: Sherief.emam@tu-ilmenau.de.

change in yet unsatisfied consumer needs. Both arguments received critique. The demand pull approach would be too broad as a concept to be useful. It would be inadequate to explain discontinuous change as the most important source of progress. Firms would not have sufficient capabilities to identify consumer needs, nor would they have the chance to choose from a ready-made stock of technological solutions to come to grips with consumer needs. It neglects the role of technological opportunities. The technology-push argument has been strongly criticized as it ignores the role of prices as incentive to invest in new technologies. With respect to technology policies, as Nemet (2009) points out, a consensus has evolved that both types of instruments: demand-pull and technology-push policies should be pursued as market conditions (to which the demand-pull argument relates to) and technological opportunities (the basis for the technology push argument) have to coincide in order to lead to technological progress. On these grounds, we will focus on the demand pull argument and try to find out whether increasing oil prices (changing market conditions), as indicator for a steadily increasing demand for energy and the general perception of dwindling fossil energy resources, make countries increase their innovative activities in order to boost technological progress in alternative renewable energy technologies. Our work draws to a large extent on Nesta et al. (2014), Johnstone et al. (2010) and Nemet (2009).

As in Johnstone et al. (2010) and Nesta et al. (2014) we apply negative binomial regression and extend our empirical exercise with estimators allowing for non-stationary heterogeneous panels suggested by Blackburne and Frank (2007), which allows, besides traditional fixed-effects estimation, also the estimation of the *mean-group* estimator (MG) (Pesaran et al., 1999) and the *pooled mean-group* estimator (PMG) put forward by Pesaran and Smith (1995). Thus we try to differentiate long-run and short-run effects.

In section II we refer to related work on the determinants of the technological progress in renewable energies. Section III presents the construction of our data and the methodological specifications we use. Results delivered by negative bino-

mial count data models will be discussed in section IV. These results will be compared with the results of dynamic heterogeneous panel estimation in section V. Section VI discusses primarily discusses shortcomings/caveats and concludes.

II. RELATED WORK AND RESEARCH QUESTION

Economic growth hinges on the disposability of energy. As Stern (2011) points out, energy scarcity is a main constraint for economic growth. The industrial revolution impressively showed that the invention of new technologies that drove economic growth was based on the usage of fossil fuels. This was key to substitute human labor for automated labor and thus enhance economic growth. Ever since the world economy has been growing, and so has the consumption of fossil fuels. A side effect of the steady increase in demand for fossil fuels has been rising energy prices. Standard textbook economics tells us about the consequences of increasing (relative) prices: all market participants will adapt their behavior. if fossil fuels become more expensive relative to non-energy goods, (1) the demand for energy should go down, as consumers adapt their behavior. They try to substitute energy-intensive goods for non-energy goods. Quite similarly, (2) the supply side will change its behavior as well. Producers will try to innovate on energy-efficient products and technologies. They try to find less expensive substitutes (Newell et al., 1999). Last not least, (3) policy makers will participate in this process, too. Legitimizing their interventions by market failure, they carry out reforms to foster renewable energy sources and, at the same time, try to fight negative externatlities such as greenhouse gas emissions or the potential risks involved in nuclear waste as a by-product of electricity production. Hence, renewable energies should be attractive for all market participants: policy makers, consumers and suppliers. Renewable energies make us believe that they can be supplied at almost zero marginal costs and no negative externalities. All what remains to be done is to develop and employ such new energy sources and to build the required infrastructure.

In traditional theory, markets should do the job, and as Newell et al. (1999) concludes, rising energy prices should eventually lead to increasing innovative activities. This hypothesis we want to test empirically in this paper to answer the following research question:

> *Research Question:* Do rising oil prices induce technological progress in renewable energies?

Meanwhile, this topic of technological progress in renewable energies and its determinants have been investigated intensively. Johnstone et al. (2010) and Nesta et al. (2014) give an excellent overview to this strand of literature. By and large, there are two fundamental options to boost technological progress – and this we can already conclude from Newell et al. (1999): either leave it to the market (Nesta et al., 2014; Sanyal and Ghosh, 2012) or try to induce innovation by policy intervention (Nesta et al., 2014; Acemoglu et al., 2012; Johnstone et al., 2010). In many countries, market liberalization has intensified competition. Along with an increasing demand for renewable energy sources, due to a growing consumer awareness to environmental issues, innovative activity has risen. Many countries also carried out policy reforms to stimulate the innovation and adoption of renewable energy technologies (Johnstone et al., 2010; International Energy Agency, 2004). However, it is not obvious to what extent rising energy prices actually contribute to increasing innovative activities. If we can shed light on this, we will, at the same time, gain insights on the question how well the price mechanism and the market for energy work as a whole.

III. DATA

As dependent variable to measure innovative activity in renewable energy technology, we collected patent statistics from European Patent Office Worldwide Patent Statistics Database PATSTAT (EPO, 2012) and focused on patents related to wind power technologies**?** Oil prices were retrieved from the Federal Reserves Eco-

nomic Data (FRED)database. As further controls we included GDP, financial development funding, and electricity consumption all downloaded from the World Bank database. Research and development data stem from the OECD database. The time span of annual data covered ranges from 1970 to 2010.

Table I: DATA PROPERTIES AND SOURCES

Variable	Label	Source	Unit
PatNumb	# of patents	PATSTAT 2012	counts
GDP	gross domestic product	World Bank DB	In Millions $
Fdev	financial development	World Bank DB	% of GDP
R&D	research and development funding	OECD database	bn.$
OilPrice	oil price	Dow Jones & Company	Ind $
ElecConsump	Electrical Consumption	World Bank DB	MWh

A higher GDP stands for a country's potential to generate technological progress in general. Industrialized countries manage to patent far more than less developed ones. As a further control we introduce financial development, which gives indications to the investment activity within a country. Financial development can be measured in various ways. The ratio of broad Money (M2) to GDP e.g. expresses the overall size of the financial intermediary of the country. Or, it can be expressed in terms of domestic credit to private sector to GDP (Hamdi et al., 2013; Fernandez and Galetovic, 1994; Calderón and Liu, 2003; Khan and Semlali, 2000). Due to missing data in the M2 indicator, we calculate financial development as the ratio of domestic credit of the private sector to GDP.

An increase in credit offered for private sector should lead to an increase in patents counts. R&D is included as a major input factor in generating technological

progress. Hence, a positive impact of R&D on patent counts should be expected. With the consumption of electricity patenting activities should also increase, as producers try to escape the shortage in its supply. Table I depicts the sources and units of our data.

Table II: DESCRIPTIVE STATISTICS

	Mean	Std. Dev.	Min.	Max.	N
PatNumb	414	28.14	57.85	0	393
GDP	11.555	1.467	8.023	15.186	504
Fdev	87.047	43.39	20.749	227.753	501
R&D	1.647	1.552	0.015	10.497	417
OilPrice	24.477	15.358	3.4	72.400	504
ElecConsump	0.878	0.545	0.142	2.559	504

Table III: CROSS-CORRELATION TABLE

		(1)	(2)	(3)	(4)	(5)	(6)
(1)	PatNumb	1.00					
(2)	OilPrice	0.34	1.00				
(3)	GDP	0.60	0.17	1.00			
(4)	RD	−0.07	0.27	−0.15	1.00		
(5)	Fdev	0.60	0.36	0.58	0.00	1.00	
(6)	ElecConsump	−0.08	0.07	0.03	0.14	−0.02	1.00

Descriptive statistics can be found in Table II. With respect to patents, we confined the analysis on all world-wide patents on wind power. Table III shows the pairwise correlations between dependent variable and all covariates. From visual inspection multicollinearity seems not to be a problem. We also perform a multicollinearity test with the variance inflated factor (vif) and did not find multicollinearity among regressors.

In the following, negative binomial regressions provide first preliminary results with respect to our research question, whether oil prices have an effect on innovative activities among in respective countries.

IV. NEGATIVE BINOMIAL REGRESSIONS

For a start, negative binomial regression were run. The dependent variable is count data and because of over dispersion, negative binomial regressions had to be preferred to a poisson model. We introduce variables sequentially to see whether there are changes in the estimates, when further covariates are considered. All covariates are instrumented by their one year lag. All models in this table are fixed-effects models taking a full set of year dummies into account. Model (1) in Table IV is a univariate regression of *PatNumb* on *OilPrice*. The correlation suggests a positive relationship between rising oil prices and patent counts. With *GDP* as a first control, *OilPrice* remains positive and significant, and so does *GDP*. Model (3) takes additional control variables into account, that is, *R&D*, *Fdev*, and *ElectConsump*. The coefficients of OilPrice and GDP change little, they are positive and the correlation is significant to the 1% level.

From the three variables introduced only *Fdev* has a significant, positive effect on the number of patents generated in a country. *R&D* and *Fdev*, however, are insignificant. In model (4) all variables are logged. The fixed-effect model applied here does not change the basic relations ship between the dependent variable and the independent variables. Model (5) differs from model (4) in this regard, that all logged variables are in differences, in other words, model (5) regresses lagged growth rates. The interesting observation in this model is that all variables which are significant in the previous models become insignificant, whereas *R&D* and *ElecConsump* all of a sudden have a significant effect, a positive effect with respect to *R&D* and a negative effect with respect to *ElecConsump*. A change in R&D funding has a positive effect on patent counts, the absolute amount of R&D does not.

The same holds for *ElecConsump*. An positive change in electricity consumption explains a decreases in patent counts, the absolute value, however, does not.

We are aware that these results are very rudimentary. But what we can infer is that there are differences in the time patterns. An increase in R&D funding as short-term impulse may enhance patenting and a short-term positive change in electricity consumption seems to reduce patent counts. Models (1) to (3) suggest that there might be a positive long-term relationship between oil prices, GDP and patent counts. As most of these variables are cointegrated, a robust conclusion cannot be drawn from these results. Furthermore, spurious regression and endogeneity problems qualify these results even more. In order to face those problems, we apply dynamic heterogeneous panel models which offer alternative estimators in addition to the traditional fixed-effects estimator, i.e. the pooled mean-group estimator by Pesaran and Smith (1995) and the mean-group estimator by Pesaran et al. (1999) (Blackburne and Frank, 2007).

Table IV: REGRESSION 1: NEG. BIN (1-3), PANEL FIXED EFFECTS (4-5)

Dependent Variable: PatNumb (model: 1-3) log (PatNumb) (model: 4-5)

	(1)	(2)	(3)	(4)	(5)
OilPrice	0.038**	0.030***	0.025***	0.917***	-0.607
	(0.016)	(0.006)	(0.006)	(0.350)	(0.531)
GDP		0.003***	0.002***	0.397*	-0.186
		(0.000)	(0.000)	(0.228)	(0.424)
RD		0.017	-0.002	-0.139	0.491***
		(0.025)	(0.024)	(0.098)	(0.148)
Fdev			0.005***	0.333***	0.047
			(0.001)	(0.119)	(0.244)
ElectConsump			-0.113	-1.029	-5.207*
			(0.237)	(1.039)	(2.829)
Constant	0.192	0.641*	0.599	-2.730***	1.792***
	(1.063)	(0.366)	(0.372)	(0.674)	(0.278)
Observations	408	377	375	375	364
Number of country1	14	14	14	14	14
LL	-1288	-1128	-1110	-255.4	-248.4

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Dynamic Heterogeneous Panel Models

In this subsection, we introduce the general model of dynamic heterogenous panel estimation as presented by (Blackburne and Frank, 2007) and will then adapt this model to our example.

General Model

In the general model it is assumed that the input data on time period , $t = 1,2,\ldots,T$, and cross section groups, $i = 1,2,\ldots,N$, can be estimated by an autoregressive distributive lag (ARDL) model $(p, q, .., q_k)$ as in the following:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (1)$$

where X_{it} is the $(k \times 1)$-vector of explanatory variables, μ_i the group specific effect, λ_{it} the $k \times 1$ coefficient vectors and λ_{ij} a scalar of constants. As T is large enough each group can be estimated separately and the variables in eq:1 are cointegrated and $I(1)$, then the error term is an $I(0)$ process for all i, thus the error correction equation can be reparameterized:

$$\Delta y_{it} = \phi_i y_{i,t-1} - \beta'_i X_{it} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \delta'^*_{ij} \Delta X_{i,t-1} + \mu_i + \varepsilon_{it} \quad (2)$$

for $i = 1,2,\ldots,N$ and $t = 1,2,\ldots,T$ where the error correction speed of adjustment is parameter expressed by

$$\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij}), \quad (3)$$

$$\beta_i = \sum_{j=0}^{q} \delta_{ij}, \quad (4)$$

$$\lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{im} \qquad j = 1,2,\ldots,p \quad (5)$$

and

$$\delta^*_{ij} = -\sum_{m=j+1}^{q} \delta_{im} \qquad j = 1,2,\ldots,q-1 \quad (6)$$

assuming that the ARDL model in eq: 1 is stable in that the roots of $\sum_{j=1}^{p} \lambda_{ij} z^j = 1 \quad i = 1,2,\ldots,N$ lie outside the unit circle, ensuring that the error correcting speed of adjustment term $\phi_i < 0$. This indicate that there is a long run relationship between dependent variable y_{it} and controllers x_{it} and is defined by

$$y_{it} = -(\beta'_i / \phi_i) x_{it} + \eta_{it} \quad (7)$$

Adapted Model

Adapting the general model from above to our case renders the long run function:

$$patnum_{it} = \theta_{0t} + \theta_{1t}GDP_{it} + \theta_{2t}OilPrice_{it} + \theta_{3t}RD_{it} + \theta_{4t}Fdev_{it} + \theta_{5t}ElectConsump_{it} + \mu_i + \varepsilon_{it} \tag{8}$$

where $i = 1,2,..,N$ is the number countries in our panel. $t = 1,2,..,T$ the time span of the panel, and $patnum_{it}$ the real number of patents per country i in period t.

The variables are $I(1)$ and cointergrated. Hence, the ARDL(1,1,1) dynamic panel specification of 8 is

$$\begin{aligned} \Delta PatNumb_{it} &= \phi_i(PatNumb_{it-1} - \theta_{0i} + \theta_{1i}GDP_{it} + \theta_{2i}OilPrice_{it} + \\ &\theta_{3i}RD_{it} + \theta_{4i}Fdev_{it} + \theta_{5i}ElectConsump_{it}) \\ &+\delta_{11i}\Delta GDP_{it} + \delta_{21i}\Delta OilPrice_{it} + \delta_{31i}\Delta RD_{it} + \delta_{41i}\Delta Fdev_{it} \\ &+\delta_{51i}\Delta ElectConsump_{it} + \varepsilon_{it} \end{aligned} \tag{9}$$

where $\phi_i = -(1-\lambda_i)$, $\theta_{0i} = \frac{\mu_i}{1-\lambda_i}$, $\theta_{it} = \frac{\delta_{i0i}+\delta_{i1i}}{1-\lambda_i}$, and $\phi_i = -(1-\lambda_i)$. The error correction speed of adjustment parameter is ϕ_i. The long run coefficients $\theta_{1i}, \theta_{2i}, \ldots, \theta_{Ni}$ are of primary interest.

Estimators for heterogeneous slopes: So far the two introduced models do not handle macro panel problems. Micro panels, i.e. small *T* and large *N* , usually relies on either fixed- or random-effects estimators or a combination of both including instrumental variable estimators such as the Generalized Method Of Moments (GMM) put forward by Arellano and Bond (1991). It requires pooling individual groups and allows for different intercepts across groups.

As a rule, macro panels do not fulfill the assumption of homogeneous slope parameters (Phillips and Moon, 2000; Im et al., 2003). In contrast to micro panels the issue of non-stationarity plays a more important role. When *T* becomes large, it is necessary to pay more attention to serial correlation, when shocks whether temporary or persistent bias estimation results. Traditional nonstationary panels with a short time span *T* have different characteristics (Phillips and Moon, 2000). Analyzing panel data with large *T* in this paper, we draw on techniques introduced by Pesaran and Smith (1995) and Blackburne and Frank (2007), which allow estimating nonstationary dynamic panels heterogeneous parameters across groups: the mean-group (MG), pooled mean group (PMG), and dynamic fixed effects (DFE) estimators.

The MG estimator depends on estimating *N* time series regressions and averaging the coefficient (Pesaran and Smith, 1995). PMG is based on a combination of pooling and averaging coefficients (Pesaran et al., 1999). The dynamic fixed-effects estimator (DFE) is similar to the PMG estimator. Both restrict the coefficients of the cointegrating vector to be equal across all panels. The fixed-effects model additionally restricts the speed of the adjustment coefficient to be equal to the short-run coefficients.

V. DYNAMIC HETEROGENEOUS ESTIMATORS

The regressions in this section refer to the heterogeneous panel techniques discussed above. All three estimators, PMG, MG and DFE, are applied in order to investigate short-run and long-run effects. The preliminary findings, depicted in Table IV, give some indications to possible short-run and long-run effects. Therefore, we consider R&D and electricity consumption to also have short-run effects on innovative activities. In Table V all three model results are reported with two model versions each.

In all models, model (6) to model (11), we introduced *R&D* and *ElectConsump* as short-term variables and also as

variables for the long run. Persistent R&D investments should, in the long run, increase the country stock of knowledge captured in new technologies and human capital. Further long-term explanatory variables are *GDP*, *Fdev* and *OilPrice*, the latter as the variable of our interest. Note that these variables are the same as in our negative binomial regressions above. The two model versions of each estimation approach differ only in the (non-)inclusion of *ElectConsump*. Comparing all six models, we observe that the error correction coefficient (*ec*) is positive and significant in all models. This suggests that the time series components are serially correlated. In model (6-9) R&D seems to have a short-term effect on patent counts.[1]

[1] We used a five-year forward window of patent counts to take into account that the time span between innovative activities and the resulting actualization of innovation can take several years. Compare e.g. Nesta (2008).

Table V: REGRESSION 2: POOLED-MEAN-GROUP(PMG) (6-7), MEAN-GROUP (8-9) AND DYNAMIC FIXED-EFFECTS (10-11)

Dependent Variable: PatNumb

		(6)	(7)	(8)	(9)	(10)	(11)
		PMG	PMG	MG	MG	DFE	DFE
short run	ec	1.018***	1.018***	0.875***	0.842***	1.045***	1.045***
		(0.073)	(0.072)	(0.114)	(0.124)	(0.011)	(0.011)
	D.RD	5.784**	5.605**	18.555**	14.736**	-0.696	-0.836
		(2.475)	(2.468)	(7.812)	(6.446)	(2.238)	(2.249)
	D.ElectConsump	131.473	133.617	-477.713	-485.562	-15.419	-13.202
		(108.852)	(109.555)	(499.072)	(488.092)	(75.411)	(75.550)
long run	OilPrice	0.177***	0.168**	-0.486	-1.116	0.546**	0.557**
		(0.065)	(0.06)	(0.835)	(1.122)	(0.256)	(0.256)
	GDP2	-0.084***	-0.079***	-2.285	-2.283	-0.181***	-0.184***
		(0.016)	(0.016)	(1.746)	(1.575)	(0.021)	(0.022)
	RD	2.127***	2.031***	34.015	40.263	-2.041	-1.818
		(0.434)	(0.471)	(22.485)	(32.712)	(1.528)	(1.560)
	Fdev	0.036*	0.043*	-0.880	-1.242	-0.237***	-0.258***
		(0.020)	(0.023)	(1.413)	(2.512)	(0.071)	(0.076)
	ElectConsump		-4.498***		-274.220		12.671
			(1.364)		(223.733)		(17.875)
		Constant	3.234	0.309	-78.869	-137.879	
			(6.235)	(6.131)	(66.371)	(106.134)	
		Observations	286	286	286	286	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Electricity consumption has no significant explanatory power. Looking at the long-run coefficients *OilPrice* has a positive effect on patent counts, a preliminary result which corroborates our research hypothesis that it should have such an effect on innovative activities. In models (8) and (9), this effect vanishes, that is, it becomes insignificant. *GDP* has a negative long-run effect on patenting in renewable energy in all six models, although in model (8) and (9) this effect is insiginifcant. A possible explanation could be that economic growth is uncoupled from the progress in renewable energy technologies. To recall, we only consider

wind power patents so far, which gives us a rather blurred picture of the role of renewable energy technologies. The sign of its coefficient is consistently negative. The reported long-run effects of R&D investments deliver only in model (6) and (7) a positive significant effect. In all other modells it is insignificant. The sign of financial development (*Fdev*) is ambiguous. In model (6) and (7). *Fdev*, i.e. the share of credits to the private sector as a percentage of GDP, appears as a positive driver of patenting in this field. In model (8) and (9) this effect is insignificant and in modell (10) and (11) we observe flipped and significant signs. Electricity consumption (model 7) has a significant and negative long-run effect on patent counts. When comparing model (6) and (7), we observe that introducing *ElecConsump* does not change a lot with regard to the other coefficients. So far, this can be interpreted as an indication for these two models' robustness.

There is no need for denying that the results in Table V are mixed. This calls for further research efforts on our side. Nevertheless, the Hausman test suggests that the PMG estimator is to be preferred over the MG and DFE estimator. This is good news with regard to the effect of *OilPrice*, *R&D* and *Fdev*. All thress are positive, which is consistent to the results in the negative binomial regressions above.

VI. DISCUSSION, CAVEATS AND CONCLUSION

At the current stage of this paper, there is not much need for discussing the results any further. This is pretty much work in progress and there are many shortcomings and caveats which have to be considered as we progress.

From an econometric stance, more tests have to be performed to understand the characteristics of the panel time series. This hopefully sheds more light on the inconsistencies identified. A further option is to compare the models with other models such as a pre-sample mean count data specification used in Nesta et al. (2014). It is conceivable that this could explain the negative sign of the long-run effects of *GDP*. Moreover, the paper by Nesta et al. (2014) also gives good advice on further factors that have an impact on innovative activities in the field of renewable energies. For example, to weight patent counts by patent family or by

their triadic relationship to adjust for patent quality make a difference. Industry dynamics play an important role, too. Many countries liberalized their energy markets in recent years. This has increased market competition and the ongoing technological progress in renewable energies driven by small start-up firms change the industry dynamics (Klepper, 1997, 1996; Abernathy and Utterback, 1978). This scrapes off a some of the market power of large incumbent firms. Another aspect is the role of global warming that has risen consumer awareness to environmental issues. The demand for renewable energies has been steadily increasing Nesta et al. (2014). Even households become energy producers, as is the case in Denmark where the majority of wind power plants are owned by households Hadjilambrinos (2000). From the viewpoint of policy making, policy reforms adapt the institutional frame of energy markets to the new needs. Consumers are drawn in to participate in energy production. An example for having introduced such demand side policies is the US (Loiter and Norberg-Bohm, 1999). Finally, the interplay between industrial change and policy reforms needs attention in our work, too. Nesta et al. (2014) provide evidence for such kind of endogeneity issues.

For the time being, it remains our positive attitude that we will find convincing evidence of the oil price impact on countries' innovative activities in renewable energies.

REFERENCES

Abernathy, W. J., Utterback, J. M., 1978. Patterns of industrial innovation. Technology Review (80), 41–47.

Acemoglu, D., Aghion, P., Bursztyn, L., Hemous, D., 2012. The environment and directed technical change. American Economic Review 102, 131–66.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. The review of economic studies 58 (2), 277–297.

Blackburne, E. F., Frank, M. W., 2007. Estimation of nonstationary heterogeneous panels. Stata Journal 7 (2), 197.

Calderón, C., Liu, L., 2003. The direction of causality between financial development and economic growth. Journal of Development Economics 72 (1), 321–334.

Fernandez, D., Galetovic, A., 1994. Schumpeter might be right–but why? explaining the relation between finance, development and growth. Johns Hopkins University SAIS Working Paper in International Economics (96-01).

Hadjilambrinos, C., 2000. Understanding technology choice in electricity industries: a comparative study of France and Denmark. Energy Policy 28 (15), 1111–1126.

Hamdi, H., Hakimi, A., Sbia, R., 2013. Multivariate granger causality between financial development, investment and economic growth: Evidence from tunisia. Journal of Quantitative Economics 11 (1&2), 111–129.

Im, K. S., Pesaran, M. H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of econometrics 115 (1), 53–74.

International Energy Agency, 2004. Renewable energy – market and policy trends in IEA countries. Tech. rep., IEA, Paris.

Johnstone, N., Hascic, I., Popp, D., 2010. Renewable energy policies and technological innovation: Evidence based on patent counts. Environmental and Resource Economics 45, 133–155.

Khan, M. S., Semlali, A. S., 2000. Financial development and economic growth: an overview. International Monetary Fund. Klepper, S., June 1996. Entry, exit, growth, and innovation over the product life cycle. American Economic Review 86 (3), 562–583.

Klepper, S., 1997. Industry life cycles. Industrial and Corporate Change 6 (1), 145–81.

Loiter, J., Norberg-Bohm, V., 1999. Technology policy and renewable energy: public roles in the development of new energy technologies. Energy Policy 27, 85–97.

Nemet, G. F., 2009. Demand-pull, technology-push, and government-led incentives for non-incremental technical change. Research Policy 38 (5), 700–709.

URL. http://www.sciencedirect.com/science/article/pii/S0048733309000080

Nesta, L., 2008. Knowledge and productivity in the world's largest manufacturing corporations. Journal of Economic Behavior and Organization 67 (3-4), 886–902.

Nesta, L., Vona, F., Nicolli, F., 2014. Environmental policies, competition and innovation in renewable energy. Journal of Environmental Economics and Management 67 (3), 396–411.

URL. http://www.sciencedirect.com/science/article/pii/S0095069614000060

Newell, R., Jaffe, A., Stavins, R., 1999. The induced innovation hypothesis and energy-saving technological change. The Quarterly Journal of Economics 114 (3), 941–975.

Pesaran, M. H., Shin, Y., Smith, R. P., 1999. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association 94 (446), 621–634.

Pesaran, M. H., Smith, R., 1995. Estimating long-run relationships from dynamic heterogeneous panels. Journal of econometrics 68 (1), 79–113.

Phillips, P. C., Moon, H. R., 2000. Nonstationary panel data analysis: an overview of some recent developments. Econometric Reviews 19 (3), 263–286.

Sanyal, P., Ghosh, S., 2012. Product market competition and upstream innovation: Theory and evidence from the US electricity market deregulation. Review of Economics and Statistics forthcoming.

Stern, D. I., 2011. The role of energy in economic growth. Annals of the New York Academy of Sciences 1219 (1), 26–51. URL http://dx.doi.org/10.1111/j.1749-6632.2010.05921.x

Diskussionspapiere aus dem Institut für Volkswirtschaftslehre der Technischen Universität Ilmenau

Nr. 42 *Steinrücken, Torsten; Jaenichen, Sebastian:* Wer ist wirklich reich? - Zu Problemen der Wohlfahrtsmessung durch das Bruttoinlandsprodukt, April 2005.

Nr. 43 *Steinrücken, Torsten; Jaenichen, Sebastian:* Wo bleiben die Subventionssteuern? - Probleme des Beihilfenrechts und ein alternatives Regulierungskonzept, Mai 2005.

Nr. 44 *Jaenichen, Sebastian; Steinrücken, Torsten; Schneider, Lutz:* Zu den ökonomischen Wirkungen gesetzlicher Feiertage - Eine Diskussion unter besonderer Berücksichtigung der Arbeitszeitpolitik, Juni 2005.

Nr. 45 *Kuchinke, Björn A.:* Qualitätswettbewerb zwischen deutschen Akutkrankenhäusern unter besonderer Berücksichtigung von DRG und Budgets, Juni 2005.

Nr. 46 *Kuchinke, Björn A.; Walterscheid, Heike:* Wo steht der Osten? Eine ökonomische Analyse anhand von Wohlfahrts- und Happinessindikatoren, Juni 2005.

Nr. 47 *Kuchinke, Björn A.; Schubert, Jens M.:* Staatliche Zahlungen an Krankenhäuser: Eine juristische und ökonomische Einschätzung nach Altmark Trans und der Entscheidung der Kommission vom 13.7.2005, August 2005.

Nr. 48 *Steinrücken, Torsten; Jaenichen, Sebastian:* Überkapazitäten zur Absicherung politischer Risiken und Instrumente finanzwirtschaftlicher Gegensteuerung, November 2005.

Nr. 49 *Jaenichen, Sebastian; Steinrücken, Torsten:* Opel, Thüringen und das Kaspische Meer, Januar 2006.

Nr. 50 *Kallfaß, Hermann H.:* Räumlicher Wettbewerb zwischen Allgemeinen Krankenhäusern, Februar 2006.

Nr. 51 *Sickmann, Jörn:* Airport Slot Allocation, März 2006.

Nr. 52 *Kallfaß, Hermann H.; Kuchinke, Björn A.:* Die räumliche Marktabgrenzung bei Zusammenschlüssen von Krankenhäusern in den USA und in Deutschland: Eine wettbewerbsökonomische Analyse, April 2006.

Nr. 53 *Bamberger, Eva; Bielig, Andreas:* Mehr Beschäftigung mittels weniger Kündigungsschutz? Ökonomische Analyse der Vereinbarungen des Koalitionsvertrages vom 11. 11. 2005, Juni 2006.

Nr. 54 *Jaenichen, Sebastian; Steinrücken, Torsten:* Zur Ökonomik von Steuergeschenken - Der Zeitverlauf als Erklärungsansatz für die effektive steuerliche Belastung, Dezember 2006.

Nr. 55 *Jaenichen, Sebastian; Steinrücken, Torsten:* Wirkt eine Preisregulierung nur auf den Preis? Anmerkungen zu den Wirkungen einer Preisregulierung auf das Werbevolumen, Mai 2007.

Nr. 56 *Kuchinke, B. A.; Sauerland, D.; Wübker, A.:* Determinanten der Wartezeit auf einen Behandlungstermin in deutschen Krankenhäusern - Ergebnisse einer Auswertung neuer Daten, Februar 2008.

Nr. 57 *Wegehenkel, Lothar; Walterscheid, Heike:* Rechtsstruktur und Evolution von Wirtschaftssystemen - Pfadabhängigkeit in Richtung Zentralisierung?, Februar 2008.

Nr. 58 *Steinrücken, Torsten; Jaenichen, Sebastian:* Regulierung und Wohlfahrt in einem Modell mit zwei Aktionsparametern, März 2008.

Nr. 59 *Lehnert, Ninja M.:* Externe Kosten des Luftverkehrs - Ein Überblick über den aktuellen Stand der Diskussion, April 2008.

Nr. 60 *Walterscheid, Heike:* Reformbedarf etablierter Demokratien im Kontext dezentralisierter Gesellschaftssysteme - Grundlegende Hindernisse bei Steuersystemreformen", April 2010.

Nr. 61 *Walterscheid, Heike; Wegehenkel, Lothar:* Kostenstruktur, Zahlungsbereitschaft und das Angebot von Mediengütern auf Medienmärkten, Juni 2008.

Nr. 62 *Walterscheid, Heike; Wegehenkel, Lothar:* Wohlstand der Nationen und handlungsrechtliche Struktur eines Gesellschaftssystems, September 2008.

Nr. 63 *Dewenter, Ralf; Haucap, Justus; Wenzel, Tobias:* Indirect Network Effects with Two Salop Circles: The Example oft the Music Industry, Juni 2009.

Nr. 64 *Dewenter, Ralf; Jaschinski, Thomas; Wiese, Nadine:* Wettbewerbliche Auswirkungen eines nichtneutralen Internets, Juli 2009.

Nr. 65 *Dewenter, Ralf; Haucap, Justus; Kuchinke, Björn A.:* Das Glück und Unglück von Studierenden aus Ost- und Westdeutschland: Ergebnisse einer Befragung in Ilmenau, Bochum und Hamburg, Oktober 2009.

Nr. 66 *Kuchinke, Björn A.; Zerth, Jürgen; Wiese, Nadine:* Spatial Competition between Health Care Providers: Effects of Standardization, Oktober 2009.

Nr. 67 *Itzenplitz, Anja; Seifferth-Schmidt, Nicole:* Warum Klimakonferenzen scheitern, aber dennoch zum Wohl des Weltklimas kooperiert wird, Juli 2010.

Nr. 68 *Kallfaß, Hermann H.:* Die Aufmerksamkeit für, die Nutzung der und die Werbung in Medien in Deutschland, November 2010.

Nr. 69 *Budzinski, Oliver:* Empirische Ex-Post Evaluation von wettbewerbspolitischen Entscheidungen: Methodische Anmerkungen, Januar 2012.

Nr. 70 *Budzinski, Oliver:* The Institutional Framework for Doing Sports Business: Principles of EU Competition Policy in Sports Markets, January 2012.

Nr. 71 *Budzinski, Oliver; Monostori, Katalin:* Intellectual Property Rights and the WTO, April 2012.

Nr. 72 *Budzinski, Oliver:* International Antitrust Institutions, Juli 2012.

Nr. 73 *Lindstädt, Nadine; Budzinski, Oliver:* Newspaper vs. Online Advertising - Is There a Niche for Newspapers in Modern Advertising Markets?

Nr. 74 *Budzinski, Oliver; Lindstädt, Nadine:* Newspaper and Internet Display Advertising - Co-Existence or Substitution?, Juli 2012b.

Nr. 75 *Budzinski, Oliver:* Impact Evaluation of Merger Control Decisions, August 2012.

Nr. 76 *Budzinski, Oliver; Kuchinke, Björn A.:* Deal or No Deal? Consensual Arrangements as an Instrument of European Competition Policy, August 2012.

Nr. 77 *Pawlowski, Tim, Budzinski, Oliver:* The (Monetary) Value of Competitive Balance for Sport Consumers, Oktober 2012.

Nr. 78 *Budzinski, Oliver:* Würde eine unabhängige europäische Wettbewerbsbehörde eine bessere Wettbewerbspolitik machen?, November 2012.

Nr. 79 *Budzinski, Oliver; Monostori, Katalin; Pannicke, Julia:* Der Schutz geistiger Eigentumsrechte in der Welthandelsorganisation - Urheberrechte im TRIPS Abkommen und die digitale Herausforderung, November 2012.

Nr. 80 *Beigi, Maryam H. A.; Budzinski, Oliver:* On the Use of Event Studies to Evaluate Economic Policy Decisions: A Note of Caution, Dezember 2012.

Nr. 81 *Budzinski, Oliver; Beigi, Maryam H. A.:* Competition Policy Agendas for Industrializing Countries, Mai 2013.

Nr. 82 *Budzinski, Oliver; Müller, Anika:* Finanzregulierung und internationale Wettbewerbsfähigkeit: der Fall Deutsche Bundesliga, Mai 2013.

Nr. 83 *Doose, Anna Maria:* Methods for Calculating Cartel Damages: A Survey, Dezember 2013.

Nr. 84 *Pawlowski, Tim; Budzinski, Oliver:* Competitive Balance and Attention Level Effects: Theore-tical Considerations and Preliminary Evidence, März 2014.

Nr. 85 *Budzinski, Oliver:* The Competition Economics of Financial Fair Play, März 2014.

Nr. 86 *Budzinski, Oliver; Szymanski, Stefan:* Are Restrictions of Competition by Sports Associations Horizontal or Vertical in Nature?, März, 2014.

Nr. 87 *Budzinski, Oliver:* Lead Jurisdiction Concepts Towards Rationalizing Multiple Competition Policy Enforcement Procedures, Juni 2014.

Nr. 88 *Budzinski, Oliver:* Bemerkungen zur ökonomischen Analyse von Sicherheit, August 2014.

Nr. 89 *Budzinski, Oliver; Pawlowski, Tim:* The Behavioural Economics of Competitive Balance: Implications for League Policy and Championship Management, September 2014.

Nr. 90 *Grebel, Thomas; Stuetzer, Michael:* Assessment of the Environmental Performance of European Countries over Time: Addressing the Role of Carbon Leakage and Nuclear Waste, September 2014.