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# ICT, growth and productivity in the German energy sector – On the way to a smart grid?

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ABSTRACT

This paper examines how the German energy industry has invested in Information and Communication Technology (ICT) capital during the years 1992–2005. Using the method of growth accounting I find that the contribution of ICT investment to the growth of value-added and average labour productivity (ALP) within the German energy industry has decreased in the years 2001–2005. The reasons for this can be many. However, policy and regulation are called to remove existing barriers to ICT investment to overcome this investment reticence and to exploit productivity potentials in all stages of the energy value chain as a necessary pre-condition for building Smart Grids.

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## 1. Introduction

Many parts of our everyday lives are supposed to get "smarter," meaning that information and communication technology (ICT) is enabling more activities and processes to be steered digitally, thereby making them easier and more efficient. The development towards "digitalisation" and an "always-on"-functionality takes place in nearly all parts of the economy, pushed by the tremendous distribution of the Internet and the mobile communication infrastructure. "Smart City", "Smart Traffic" and "Smart Home" are some of the catchphrases that describe this development. For the past few years, the energy sector is operating under this new paradigm. Initiatives around the world track the idea of intelligent energy networks that is summarised under the expression "Smart Grid".[1] Specifically, in Germany there is both the need and the political will to reorganize the energy system by introducing ICT and thereby prepare it for future challenges.[2]

ICT will be essential in fulfilling the objectives of economic efficiency, security of supply and environmental sustainability that are linked with energy supply. There are different issues to be tackled in detail; the multitude of actors that entered the energy market after liberalisation must be informationally connected in such way that efficient processes are feasible among all stages of the energy value chain. In terms of generation, an increasing number of distributed sites of mainly renewable energy sources have to be integrated into the grid so that it is still controllable. The grid itself may be managed more efficiently by the ability to control loads and the generally higher information quality that results from increased data collection throughout all parts of the system. In the retail sector, the technology of smart meters will lead to a wider range of products and intensify competition. In short, substantial productivity gains in all parts of the value chain seem possible through the introduction of ICT.

To solve the described challenges and implement corresponding new and innovative procedures that raise productivity, investment in ICT is necessary (Praetorius et al., 2009). The investment in ICT can be taken as an indicator for the willingness to innovate as such investment leads to new (technical) processes and operational reorganisation.

Using the method of growth accounting, this article examines to what extent the German energy industry has tapped growth and productivity potentials by utilising ICT in the period between 1992 and 2005. If investment in ICT has taken a downturn in recent times, then policies should be implemented to form a framework for new incentives or regulations to promote ICT investments and pave the way towards a Smart Grid.

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[1] Cp. for example the Grid Wise initiative in the USA or Smart Grids Austria.

[2] For example, the German Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety currently support six model regions where the implementation of ICT into the energy system is tested ("E-Energy").

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Generally there are no empirical assessments for the energy industry on a national or international basis by the method of growth accounting yet. By contrast, one main field of the growth accounting literature is ICT productivity potential in general on the basis of empirical country comparisons (Jorgenson and Stiroh, 2000; Jorgenson et al., 2005; Fukao and Miyagawa, 2007; van Ark et al., 2008). Furthermore, country-specific studies, mainly based on the EU KLEMS[3] database are in the centre of research (Mas and Quesada, 2005; Biatour et al., 2007; Fouquin et al., 2008). Finally, single industries are subject of the analysis (Erber and Madlener, 2008; Smeral, 2009). As this paper analyses developments in the German energy industry it ranks among the last research field and is structured as follows: In Section 2 the methodology of growth accounting is described. Section 3 presents the outcomes of the productivity and growth analysis for the German energy sector with a special focus on ICT, while Section 4 concludes and provides an outlook for the future.

## 2. Methodology

The main objective of this paper is to explain the contribution of ICT to the increase in growth and productivity within the energy industry and thereby analyse the investment behaviour of utilities. The method of "growth accounting" offers the opportunity to separately consider the influence of ICT and therefore seems particularly suitable for this purpose.[4] In this section a short description of the theory of growth accounting is given. It builds the basis for the analysis of the German energy industry in Section 3.

The purpose of using growth accounting is to explain contributions of input factors to growth and productivity. The starting point of this analysis is the common form of growth accounting with decomposing industry-level value-added growth (VA) into its input factors and TFP (Jorgenson and Stiroh, 2000)[5]:

$$\Delta\ln \mathrm{VA}_{i,t} = \bar{v}_{K,i,t}\Delta\ln K_{i,t} + \bar{v}_{L,i,t}\Delta\ln L_{i,t} + \Delta\ln A_{i,t} \tag{1}$$

$K_{i,t}$ represents capital services for industry $i$ in period $t$. $L_{i,t}$ is the factor for quality-adjusted labour of industry $i$ at time $t$. $A$ reflects Total Factor Productivity (TFP).

Capital services ($K_{i,t}$) is a flowing parameter that is widely accepted as a measurement category instead of the capital stock (Roehn et al., 2007). In contrast to the capital stock—which is a state parameter—capital services are not part of the national accounting system and must be derived indirectly. It can be deducted as follows (Jorgenson et al., 2005; Roehn et al., 2007):

$$K_{i,j,t} = Q_{K,i,j}\frac{1}{2}(S_{i,j,t-1} + S_{i,j,t}) \tag{2}$$

$S_{i,j,t}$ is the capital stock of asset $j$ in industry $i$ at time $t$. $Q$ represents a proportionality factor, indicating the quality of asset $j$. This factor is often assumed to be constant over time so that all changes in quality are expressed by the price index. The marginal productivity of each input factor (e.g., a building, a computer) is deducted, which makes it possible to aggregate capital input.

$L_{i,t}$ in equation (1) is the factor for quality-adjusted labour of industry $i$ at time $t$. This factor also takes into account different marginal productivities of labour, dependent on, for example, gender, age or education level of employees. Consequently, the factor represents the aggregation of the different marginal productivities.

[3] See www.euklems.net for more details.

[4] For a detailed description of growth accounting and the role of ICT see for example Jorgenson et al. (2005).

[5] In the following it is referred to the concept of "value-added", i.e. intermediates that vanish during the production process are not accounted for.

The input shares of capital services $\bar{v}_{K,i,t}$ and quality-adjusted labour $\bar{v}_{L,i,t}$ add to unity. Considering two periods they are calculated as follows (Roehn et al., 2007):

$$\bar{v}_{h,i,t} = 0.5(v_{h,i,t} + v_{h,i,t-1}) \quad \text{with } h = K, L \tag{3}$$

The input shares can further be defined as (Schreyer, in press):

$$v_{K,i,t} = \frac{P_{K,i,t}K_{i,t}}{P_{K,i,t}K_{i,t} + P_{L,i,t}L_{i,t}} \tag{4}$$

and

$$v_{L,i,t} = \frac{P_{L,i,t}L_{i,t}}{P_{K,i,t}K_{i,t} + P_{L,i,t}L_{i,t}} \tag{5}$$

$P_{K,i,t}$ and $P_{L,i,t}$ are the prices of labour and capital. The weights of inputs are thus defined as the share of monetary assessed factors labour and capital on total input.

In addition to the question of what factors account for the growth of an industry or economy, it is also important to consider the triggers to changes in productivity. It is common to use average labour productivity (ALP) to measure these changes. ALP is defined as the ratio of output ($Y$) to hours worked ($H$):

$$\mathrm{ALP} = \frac{Y}{H} \tag{6}$$

Equation (1) can thus be transformed to (Roehn et al., 2007):

$$\Delta\ln \mathrm{ALP}_{i,t} = \bar{v}_{K,i,t}\Delta\ln k_{i,t} + \bar{v}_{L,i,t}\Delta\ln q_{i,t} + \Delta\ln A_{i,t} \tag{7}$$

The parameter $\Delta\ln k_{i,t}$ represents the growth of capital input per hour worked. It is referred to as capital deepening (cp. Jorgenson et al., 2005) and reflects an increase in capital, i.e., the substitution of labour by capital or the better fitting of the workforce with capital (Roehn et al., 2007). The parameter $\Delta\ln q_{i,t}$ represents the increasing share of hours worked by employees with a higher marginal product and thus means an increase in labour quality. The parameter $\Delta\ln A_{i,t}$ is growth in TFP; it influences ALP directly.

How can ICT be integrated in this growth accounting framework? ICT can influence growth and productivity in various ways (cp. Schreyer, 2000). First, the production of ICT products contributes to growth of the whole economy. This approach refers to the production process of ICT goods. Even if the share of this production is relatively small in terms of the total economy, its contribution to economic growth might be relatively high, so long as the ICT producing industry grows much faster than other industries.

Secondly, the contribution of ICT as capital input can be examined. This input more or less occurs within all sectors and thus allows comparisons among different industries. The factor capital is divided into ICT capital and Non-ICT capital. The process of capital deepening can proceed through the substitution of labour and non-ICT capital by ICT capital. This particularly happens when prices of ICT goods get relatively cheap in comparison with the other input factors. Equation (1) can therefore be written as:

$$\Delta\ln \mathrm{VA}_{i,t} = \bar{v}_{\mathrm{IKT},i,t}\,\Delta\ln K_{i,t}^{\mathrm{IKT}} + \bar{v}_{\mathrm{N-IKT},i,t}\Delta\ln K_{i,t}^{\mathrm{N-IKT}} + \bar{v}_{L,i,t}\Delta\ln L_{i,t} + \Delta\ln A_{i,t} \tag{8}$$

The contribution of capital is divided into $\bar{v}_{\mathrm{IKT},i,t}\Delta\ln K_{i,t}^{\mathrm{IKT}}$ (the input share of ICT capital multiplied by ICT capital services) and $\bar{v}_{\mathrm{N-IKT},i,t}\Delta\ln K_{i,t}^{\mathrm{N-IKT}}$ (the input share of non-ICT capital multiplied by non-ICT capital services).

Accordingly, after distinguishing between ICT capital and non-ICT capital, ALP can be rewritten as:

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