

# The Impact of ICT-Diffusion on Growth: The Case of Germany's ICT Sector

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## *Abstract*

*Ever since the rapid economic growth in the US in the 1990s ICT-capital has been considered as one of the primary reasons for economic growth and the Solow Paradoxon seemed to be resolved. However, the recent economic slow-down and the burst of the dotcom-bubble contradicted these findings as investments in ICT were cut down drastically. In this paper we look closer at the recent data and evaluate the German economy using a model of the ICT-sector and it's impact on the economy as a whole. By taking into account the diffusion of key technologies in different segments of the ICT-market we take a new approach on macroeconomic modelling in this area. Especially the effect of internet and the introduction of UMTS will be discussed in our projections using the system dynamics model.*

## **1. Introduction**

Opinions concerning the "Information Age" tend to differ dramatically. At the beginning of the Millennium at the top of the wave called the New Economy many proclaimed the end of the economy as we know it. Mobile communication and the Internet were to bring an end to business cycles and inflation. A digital revolution was generally considered to shape a new world order.

Now four years have passed and the high-flying hopes diminished. In Germany - like in many other countries - the ICT-sector underwent a severe recession, reaching the level of the years prior to the New Economy Hype. Even now the recovery is slow and more traditional concepts like ROI replaced the Olympic spirit<sup>1</sup> when judging the value of an IT-project.

Still there are people like the BITKOM chairman who believe that the ICT-sector alone can put an end to the ongoing recession in Germany. Does this opinion have any merit?

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<sup>1</sup> It only matters to compete at the Olympic Games, winning is only a secondary objective. Here: eBusiness and investments in IT were conducted not because of rational evaluation of investment alternatives, but in order not to miss out on the glorious future of the Information Age.

This work will give an answer to this question taking the System Dynamics approach. But it will not stop there. We will also take a look at the German UMTS auction in 2000 and its outcomes, as well as identify the growth potentials of the ICT-sector

In order to achieve this, we will conduct an extensive analyse of the German ICT sector and identify the relevant markets and their interdependencies. The resulting macroeconomic model will be validated using real market data and realistic simulation scenarios will be developed. We finish with the discussion of the simulation results and their implications. For the main part of these simulations we will consider a period until 2010. Concerning UMTS we will take a peak at the years until 2020. Of course all simulations regarding periods this long will fail to make accurate predictions if it comes to concrete figures. But then again this should not be the aim of any System Dynamics model. Trends not definite numbers are the instruments to be used when discussing the above issues.

## 2. Key Concepts

### 2.1. Defining ICT

This work follows the European Information Technology Observatory when defining the market for ICT goods. In general the ICT-sector consists of two separate markets – the market for information technology and the market for telecommunications. Each in term is divided into several smaller segments. The market for information technology (IT) is divided into the markets for IT-Hardware consisting of all kinds of computer hardware, e.g. server, workstations, computers, but also add-ons, printers and datacom hardware, Software (operating systems and applications) and IT-services (consulting, implementation, management and support). Telecommunication (TC) is split up into mobile and fixed communication as well as communication hardware and carrier services.

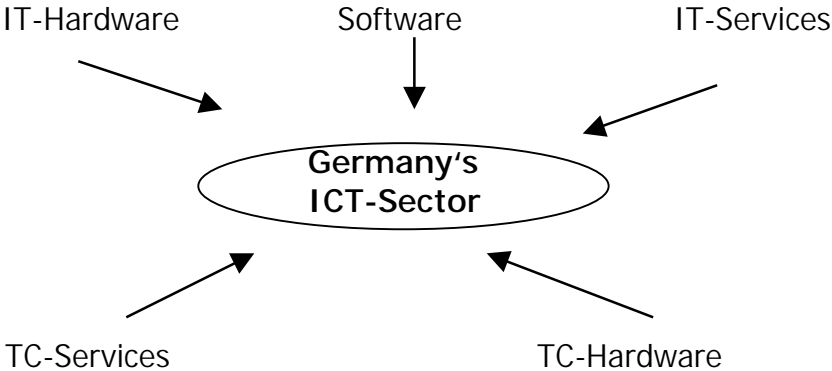


Figure 1: ICT markets according to EITO

## **2.2. Laws concerning ICT**

### **2.2.1. Moore's Law**

The oldest of all laws concerning ICT was published in 1965 when the Information Age would have been considered mere fantasy. But even today it still remains the main driving force behind all developments in information technology. It states that „*The complexity of microprocessors will double every 18 to 24 month at constant costs of production.*“. Not before 2013 anything is likely disrupt these dynamics if one is to believe Moore's statement made in December 2003. More likely, he states, it will remain with us for as long as 2020.

In any case the effects of this law are dramatic since computing power evolves in an exponential fashion which in term results in falling prices in very short periods of time. It also means that lifecycles of IT goods are shortened drastically, i.e. the average pc becomes obsolete after 2-3 years and has to be replaced. Thus it is a reasonable line of thought that IT generates it's own demand.

### **2.2.2. Metcalf's Law**

Another very important feature of ICT is that is highly dependent on it's diffusion as numerous studies have shown. Thus network externalities are extremely important in assessing the role of ICT. On the microeconomic scale network effects affect pricing standards and market structure through feedbacks and economics of scale. On macroeconomic level ICT is considered to improve information, reduce costs and therefore inflation. It also stimulates competition.

Summing up the importance of networks, Metcalf states that: „...*the value of a network goes up as a square of the number of users.*“

### **2.2.3. Solow's productivity paradox**

In 1987 Solow started a discussion that even now leads to heavy arguments when he wrote: „*We see the computer age everywhere except in the productivity statistics*“. Many explanations have been found varying from measurement errors to learning lags. Behavioural economists have also argued that irrational investment behaviour is responsible for the failure of IT to show up in the productivity statistics. As these arguments have been considered and new methods like hedonistic pricing indexes have been developed in order to measure the value of ICT products and services more accurately, there remain a few inconsistencies with the general theory of ICT driving growth. The most favourite of these being the differences in growth between USA and Western Europe. Therefore more recent research like van Ark (2003) takes a different approach and gives diffusion a key role in the shortcomings of ICT productivity. They argue that not only the investment rate is crucial but also the level of investments e.g. capital stocks. When comparing labour-productivity relative to ICT capital stock across OECD countries they find their theory supported by the most recent data. Therefore Solow's Productivity Paradox must be considered falsified.

## 2.3. Growth Accounting

The framework of growth accounting is well known in economic literature especially concerning the impact of ICT investments on growth. It originates from the neoclassical growth theory and is defined as a homogenous production function where output is a function of Labour (L), ICT Capital ( $K_{ICT}$ ), and Non-ICT Capital ( $K_N$ )

$$Y = A \times X(L, K_N, K_{ICT})$$

Assuming that constant returns of scale this formula can be transformed so that the growth rate of output is represented by the sum of the growth rates of factor input, weighted with their relative factor returns. The residual  $\Delta \ln A$  which is called multifactor productivity accounts for technological progress, changing regulations etc.

$$\Delta \ln Y = v_L \cdot \Delta \ln L + v_{K_{ICT}} \cdot \Delta \ln K_{ICT} + v_{K_N} \cdot \Delta \ln K_N + \Delta \ln A$$

This simple equation can easily be extended in order to differentiate between different kinds of Capital or different industries. When looking at capital deepening it can also be transformed to reflect labour productivity.

## 2.4. Diffusion Modelling

Originally the framework used in this work was developed by Bass in 1969. His standard model forecasts how an innovation is adopted by consumers over time. It works under the assumption of falling prices. Since it is as successful even at an aggregated level as it is predicting diffusion patterns of single products, we use it to model the adoption of the key technologies of ICT being the Internet and mobile communications.

$$Q_t = p(\bar{Q} - N_t) + q\left(\frac{N_t}{\bar{Q}}\right)(\bar{Q} - N_t)$$

$Q_t$  - additional users in period t

$\bar{Q}$  - market potential

$N_t$  - amount of users in period t

p - coefficient of innovation

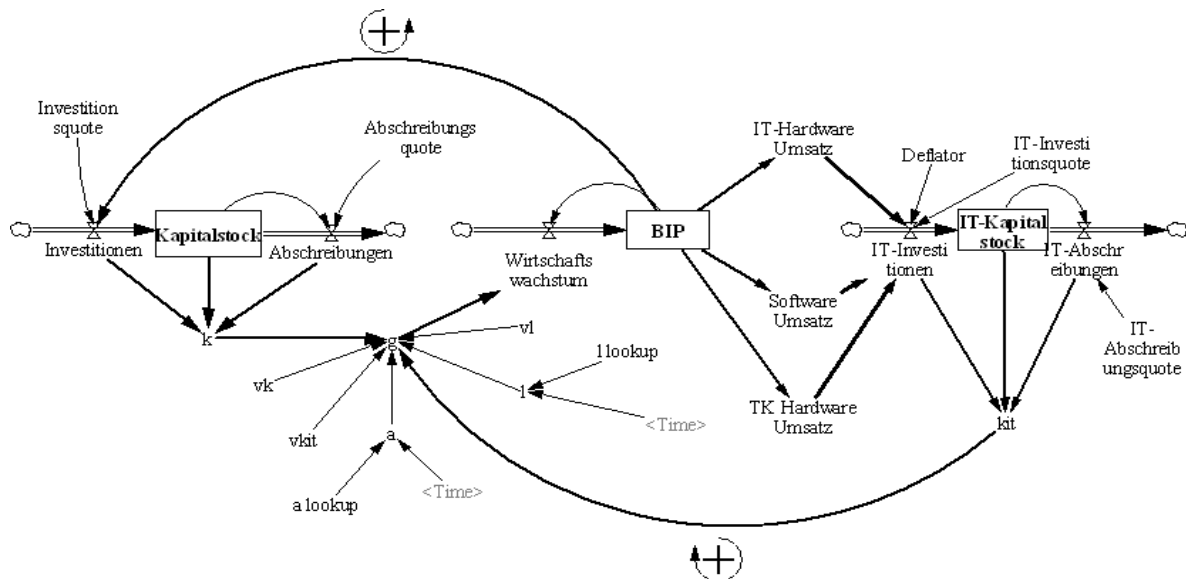
q - coefficient of imitation

Deviating from the standard model which uses a fixed market potential we adapt for population growth by setting the market potential to a fixed percentage of the population. This results in an upward sloping s-shaped curve corresponding to logistic growth which is characterized by  $\sum Q_t = \bar{Q}/(1 + e^{-a+bt})$ .

### 3. The Model

#### 3.1. The Productivity View

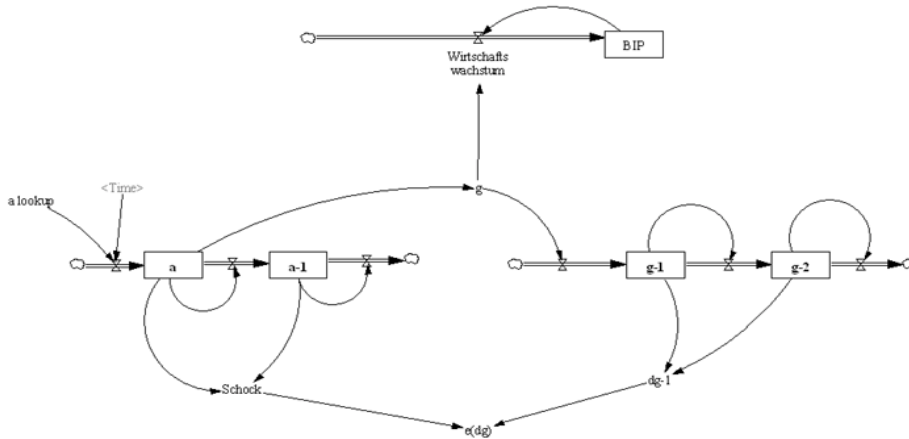
The central element of this view is real output denominated by the term BIP and it's growth. While we consider labour and technological progress as exogenous, capital plays a predominant role in computing the growth rate of output. This is shown through both feedback loops connecting the capital stocks of ICT and Non-ICT goods to output via investments.



**Figure 2: Productivity View - the Capital Feedback Loop**

In contrast to “regular” investments which we define as a fixed percentage of output investments in ICT capital calculated by using a fixed percentage of the sales from the relevant markets, e.g. IT and telecommunication hardware and software/IT-services. Carrier services are omitted because they are generally classified as consumption rather than investment. Since sales are nominal figures rather than real, we have to deflate sales in order to achieve the desired values. To reflect the special characteristics of the ICT markets in regards to Moore’s Law and it’s applicability dynamic deflators are used.

While investments as well as sales are highly dependent on output because of the general macroeconomic identity of a closed economy where spending equals output, another very important factor influences investments: expectations.

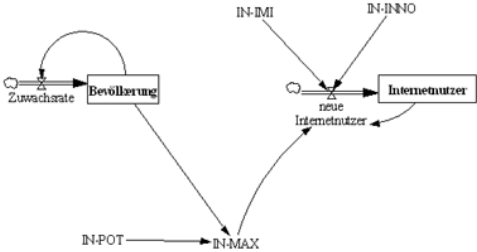


**Figure 3: Expectations and Productivity Shocks**

In our model expected growth are computed as the mean of the last change of output growth and the change in multifactor productivity. Latter part of the equation representing productivity shocks in accordance to the real business cycle theory.

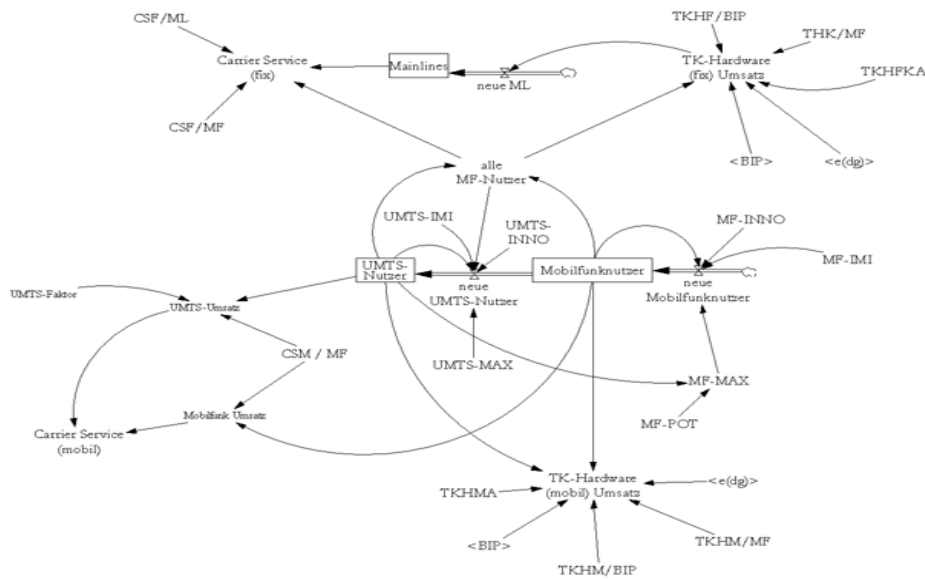
### 3.2. The Diffusion view

In the diffusion view of the model we compute the market size which determines the height of the corresponding investments in the productivity view. Besides output and expected growth the penetration of the Internet and mobile communications play a major role when calculating sales. Therefore we compute the amount of users for a these technologies using our variation of the Bass model described above and measure their impact on the market.



**Figure 4: Internet Diffusion**

In regard to Internet usage our model is straightforward while mobile communication is a quite different issue because we differentiate between “regular” mobile communications and UMTS. This differentiation is achieved by using a two-phased Bass model where the upper limit or market potential of UMTS is a fraction of all “regular” mobile communication users. Since in our model one cannot use both technologies simultaneously market potential for regular mobile communication is reduced by the number of UMTS users.



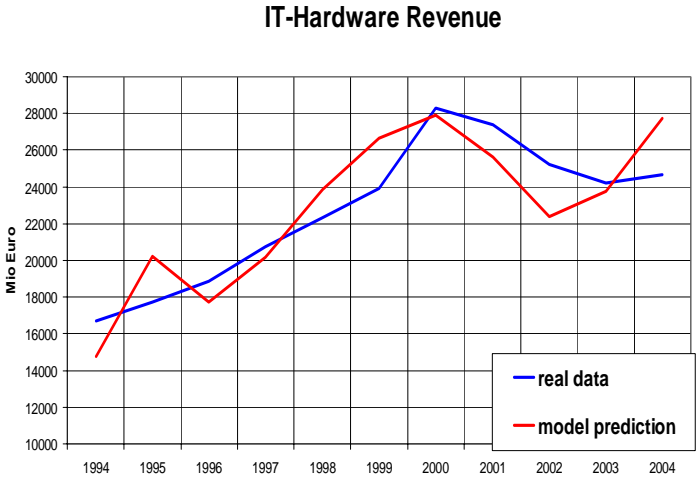
**Figure 5: Diffusion of GSM and UMTS, the telecommunication markets**

Having determined the user numbers of the key technologies and their influence on sales we take on final step before calculating them and take a look at one last factor: complementary markets. The intuition behind this factor is quite simple: computers require software, mobile phones are bought in order to communicate. Therefore hardware sales positively influence software/service sales.

## 4. Simulation Results

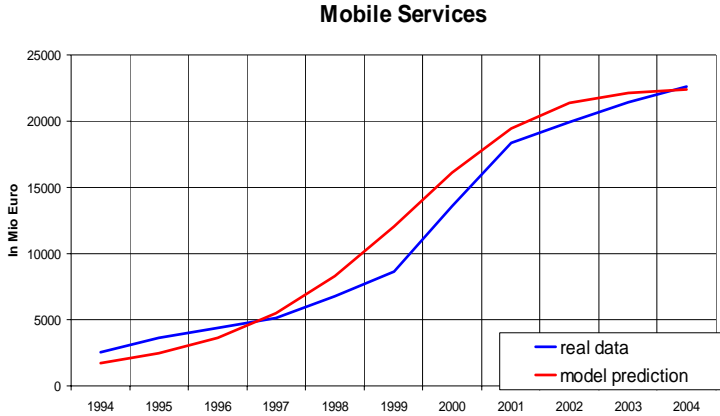
### 4.1. Validation

In order to check a model for consistency it is validated by running it with real market data. While doing so a well designed model will behave similar to the market but usually not exactly like it. A complete duplication of all values is due to simplification unrealistic.



**Figure 6: Validation (IT-Hardware)**

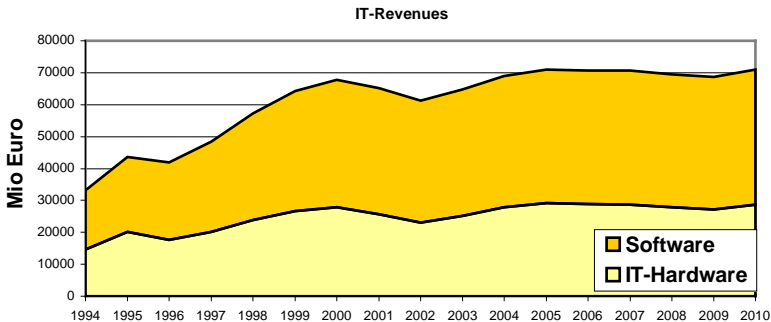
We chose the markets for IT hardware and mobile carrier services to represent our validation efforts. As figure 6 and 7 show our model maps real market behaviour quite well. IT hardware revenues behaves a little more volatile than in reality but still it fits the general behaviour. The other markets we omit at this point since their curves behave similar to figures six and seven.



**Figure 7:**  
Validation  
(Carrier Service  
– Mobile  
Communication)

## 4.2. Market development

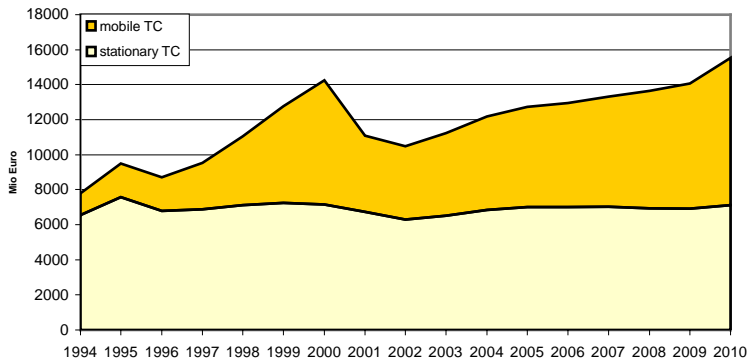
Concerning the development we examined two scenarios: stagnation of the traditional economy, e.g. all growth has to be induced by ICT, and exogenous growth. The scope of our simulation is until 2010 and we assume that the coefficients of the Bass model remain constant while UMTS users generate a 30% higher revenue when compared to “regular” users.



**Figure 8:**  
The IT sector  
and Stagnation

Our findings in the stagnation scenario are as illustrated in figures 8 through 10 that mobile communication leads the way. Information technology on the other hand does not pick up it’s rapid pace of growth from before the recession. The reason for it’s failure to do so in the model can be identified as the slow diffusion speed of the Internet usage. If the digital divide that limits internet usage in Germany to about 56,5% of the population cannot be overcome not much is to be expected of the IT sector.

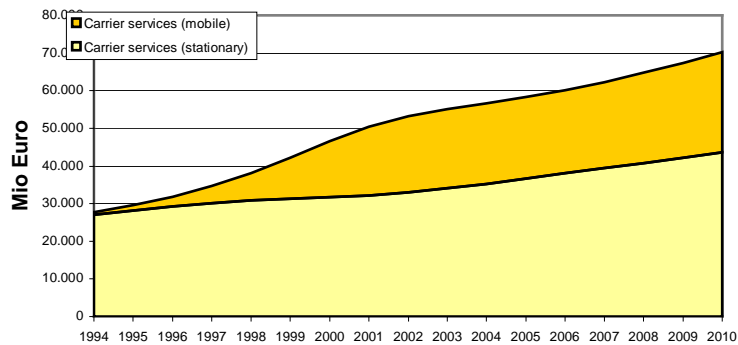
**Telecommunication Hardware Revenues**



**Figure 9:  
Telecommunication  
Hardware and  
Stagnation**

Mobile communication on the other hand behaves quite differently due the fact that UMTS was finally introduced. As figure 9 shows sales for mobile communication equipment will increase by an large amount and catch up to stationary communication sales. This also true for carrier services as depicted in figure 10. Fixed telecommunication equipment on the other hand does not participate in this surge which is no surprise as Germany's fixed communication network is now well established even in eastern part.

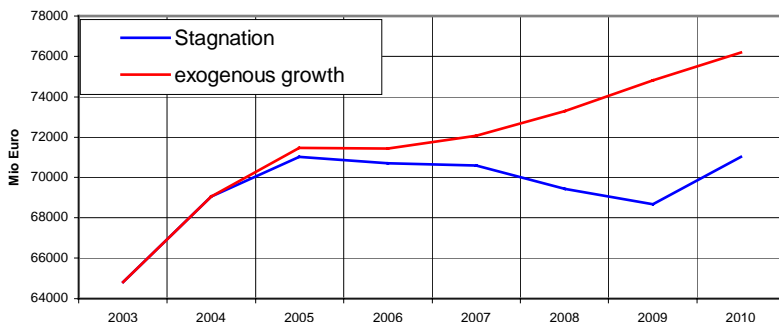
**Carrier Services**



**Figure 10:  
Carrier Services  
and Stagnation**

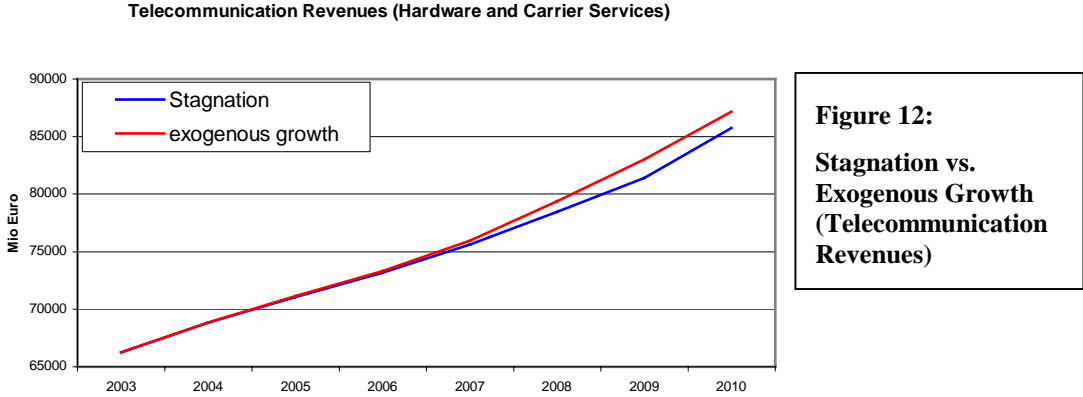
When comparing growth and stagnation scenario the findings of the stagnation scenario hold and one is not surprised to find that IT revenues are more dependent on output growth than telecommunication revenues. Again this due to the fact that UMTS induces most of the growth that is evident in telecommunications market while the economic stimulation only adds to the general growth trend.

**IT-Revenues**



**Figure 11:  
Stagnation vs.  
Exogenous Growth  
(IT-Revenues)**

As figure 11 shows economic stimulation changes the way the market for information technology behaves. In the stagnation scenario the revenues follow a business cycle like pattern, while a pick-up in overall growth leads to extended growth. The change of behaviour cannot be observed with telecommunication revenues. Even the pessimistic scenario concerning overall growth the model forecasts sales to surge by about 30%. Economic stimulation as depicted in figure 12 supports revenue growth but adds very little in absolute terms.

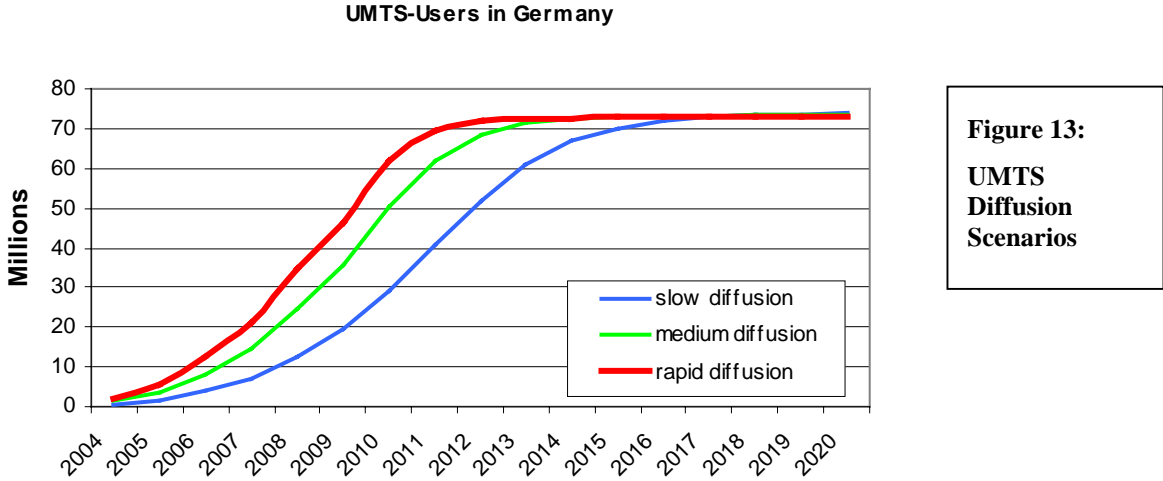


**Figure 12:**  
Stagnation vs. Exogenous Growth (Telecommunication Revenues)

### 4.3. The UMTS Auction

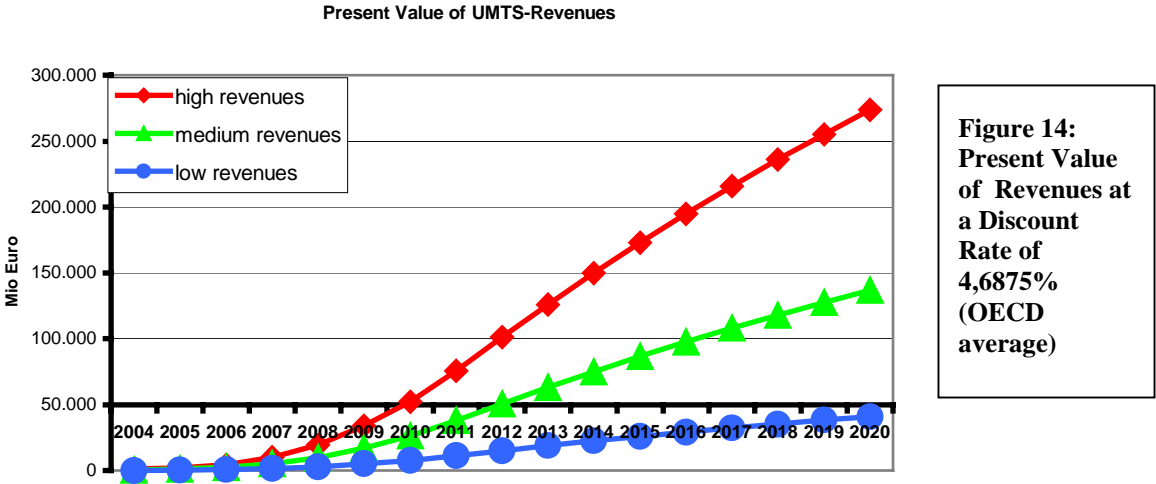
The last section showed that UMTS does indeed have a very positive effect on the telecommunication market. But does that stimulation warrant the tremendous amounts that were paid at the auction in 2000? The six bidders paid over 50 billion Euros for their licences which run until 2020.

We begin our investigation of this point with a look at three different diffusion scenarios of a period of 16 years reflecting the maximum lifetime of this investment. In all cases we assume that in the long-run UMTS will fully replace it's predecessors and will yield a higher ARPU (average revenue per user). How much higher will depend on the specific scenario as will the interest rate at which earnings will be discounted. For the sake of simplicity we will abstain from incorporating the costs of installing and running UMTS services.



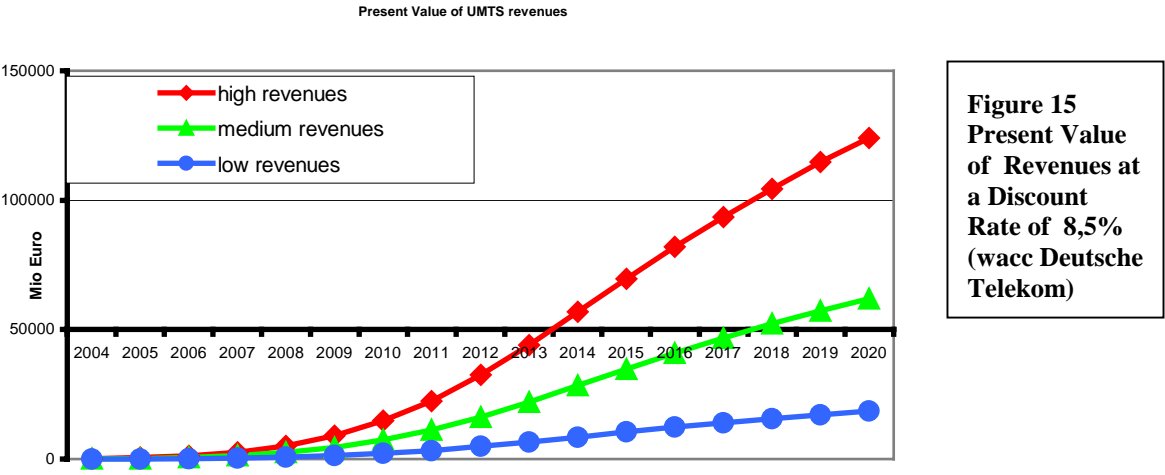
**Figure 13:**  
UMTS Diffusion Scenarios

In our first scenario we discounted revenues with the average long-term interest rate in Germany as given by the OECD. Figure 14 shows the present value of all earnings in excess of “regular” mobile communication. We assumed that the average amount customers were willing to pay more for the use of UMTS is relative to the ARPU. Simulations show that even when excess revenues are high the break-even point is not reached before 2010 when the next generation of mobile communication is expected to be fully established. In the worst case scenario with low excess revenues break-even is not attained in the lifetime of the UMTS license.



**Figure 14:**  
Present Value  
of Revenues at  
a Discount  
Rate of  
4,6875%  
(OECD  
average)

When using the weighted costs of capital as stated by one of the bidders (8,5%), matters get even worse. In the most optimistic case break-even is not established before 2014 and pessimistic scenario doesn't even reach half of the 50 billion Euros paid in 2000.



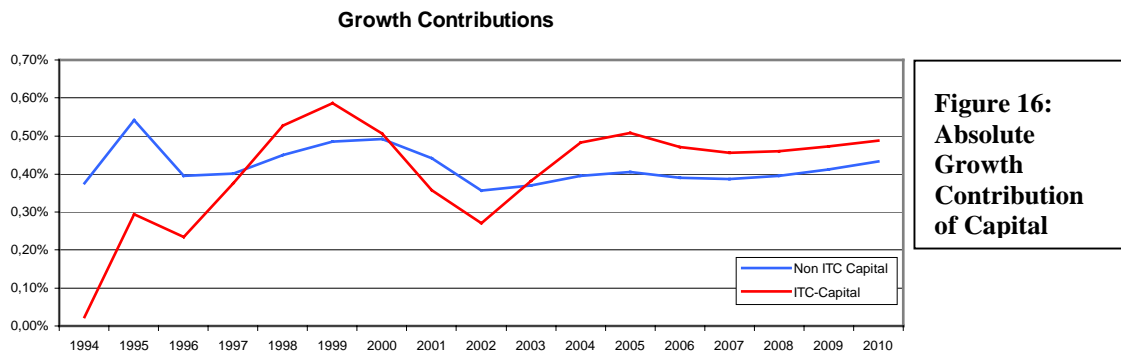
**Figure 15**  
Present Value  
of Revenues at  
a Discount  
Rate of 8,5%  
(wacc Deutsche  
Telekom)

As these figures show it is unlikely that UMTS can be considered a success-story in regard to the UMTS auction in 2000. When keeping in mind that we abstained from including installation costs in our analysis one can only wonder if losses can be averted from the bidders' point of view.

## 4.4. The Productivity Paradox Revisited

Discussions about the Productivity Paradox have raged ever since Solow mentioned it in his famous review. Does this model fall in line with it's critics like van Ark?

When taking a look at the absolute contributions to growth in figure 16 one must concede that there is no longer evidence supporting the Productivity Paradox



Although the growth contribution of ICT capital started at almost zero in 1994 it picked up during the latter half of the 1990 reaching the current level from which is not likely to stray. This behaviour supports the evidence is it a question of diffusion of ICT capital especially when keeping in mind that the share of ICT in the overall capital stock more than doubled between 1994 and 2001.

## 5. Conclusions

We set out to examine the impact of ICT on growth in Germany. In order to map the erratic behaviour of the ICT markets in the past we identified the key concepts that drive these markets - diffusion of key technologies and Moore's Law - and linked them to the well known growth accounting framework Using our model we discussed various issues backing up our arguments with our simulation results.

We found that the Productivity Paradox does not hold any longer since ICT-capital and ICT-investments will make up about half of capital driven growth. In the past, e.g. the mid 1990s and before Solow might have had a valid argument since the share of ICT capital stock was quite low in Germany. Today and in the future we fall in line with the studies conducted by an Ark and consider the Productivity Paradox no longer valid.

When examining the future development of the relevant markets it be became obvious that mobile communication rather than internet usage will drive growth. This is due to the fact that internet penetration has presumably reached it's ceiling level and is not likely to grow dramatically over the next few years. Mobile communication is not bound by such restrictions since the introduction of UMTS drives revenues and therefore growth.

Nevertheless the markets for mobile communication are still carry the burden of the investments in UMTS licences from 2000. Examining several different scenarios varying penetration rates and the consumer's willingness to pay more for UMTS, we found that he 50 billion were unrealistically high and break even will not be reached before 2010 even in the most optimistic scenario. There are even scenarios, which are no less realistic, where the present value of revenues never exceeds or even reaches the 50 billion mark during the lifetime of these licences.

Still, further refinement of the model is in order since we do not account for the intensity of usage. Also further data will have to be gathered and incorporated into the model. Nevertheless the trends identified by our model are in accordance with numerous other studies.

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