Market Access and Information Technology Adoption? Historical Evidence from the Telephone in Bavaria

Florian Ploeckl*
University of Oxford
Nuffield College and Department of Economics

November 24, 2011

Abstract

Information technology, like the telephone, influences market access, this paper answers the question about a reverse effect, does market access affect information technology, in particular its adoption. Using the historical case of the introduction of the telephone in Bavaria, I demonstrate with a rank, order and stock effects diffusion model how market access affects the diffusion of local telephone exchanges over towns as well as the rate of adoption of telephone lines within towns. The results of a duration analysis show that market access speeds up the diffusion, a spatial correlation specification demonstrates that this is not just a geographic effect. Controls show that the diffusion was dominated by economic rather than political factors. The rate of adoption within towns is also affected by the adoption of lines in other towns, the results indicate that about 4% of all lines are due to the ability to call outside your local exchange network. Market access is therefore shown to impact the adoption of technology.

Preliminary Draft: Please do not cite without permission

*, Nuffield College, University of Oxford
1 New Road, Oxford, OX11NF, United Kingdom
E-mail: florian.ploeckl@economics.ox.ac.uk

1 Introduction

The telephone, like the Internet today and the telegraph before it, was at the center of a revolution in information technology. This technological progress has had an impact on the location of economic activity, for example through its impact on information exchange, the allocation of capital as well as monitoring of investments and labor. Through the introduction of truly interactive communication possibilities it strongly reduced costs for transactions between spatially distinct locations. This implies that technological progress in information technology had (and still has) a positive impact on market access, since spatial transactions costs were (and still are) one of its central components. If this technology has a positive economic effect this might have ramifications for the adoption of technology. This paper looks therefore at the reverse effect and investigates whether market access has an impact on the diffusion of information technology. In particular I look at the spatial pattern of diffusion, which thereby provides an answer to the general question, are agglomeration effects self reinforcing through impacting transaction cost technology adoption ?

The diffusion of information technology is usually investigated either on a macro level, for example the initial adoption and penetration in different countries, or on a micro level, for example the adoption decisions of individual households or firms. The impact of market access is often investigated on a level in between the two, focusing on towns and regions. To investigate the impact I am extending the literature on technology diffusion by focusing on the spread and adoption of the telephone in towns. This is done on two levels, first the establishment of local networks in towns, which enables private phone lines, and second the adoption of phone lines within these local town networks.

The existence and utilization of increasing returns relies on the access to markets to acquire inputs and sell outputs. Required for said market access is knowledge about them and therefore the acquisition of relevant market conditions. Information technology as a consequence improves therefore the integration between markets. It also affects the allocation of resources through easier monitoring, which allows the extension of business operations. Chandler (1977) provides a prime example with the analysis of the importance of the

telegraph for the rise of large cooperations in the United States. This illustrates that technological progress in information technology reduces spatial transaction costs, not necessary in monetary terms but also by speeding up the exchange of information. The telephone did this predominantly through allowing direct interaction and communication, leading to a further increase in transaction speed over the telegraph. When spatial transaction costs decrease, the market access for particular locations increases and agglomeration forces strengthen.

If the diffusion of new information technology leads to a strengthening of agglomeration effects, and has therefore a positive effect on welfare, the question arises whether the spread of technological progress is shaped by existing agglomeration patterns. The focus here is on the impact of market access on the diffusion of new inventions rather than the invention itself. In particular I test two hypotheses about the diffusion pattern, first did towns with a larger local market as well as market access in other towns adopt the telephone faster, and second, did towns with a larger market access, i.e. more distance-weighted connections in other towns, see a faster rate of adoption of telephone lines.

These two postulated characteristics of the diffusion pattern will be analyzed with an adjusted rank, stock and order effects diffusion framework developed by Karshenas and Stoneman (1993). Rank effects are town characteristics that influence the the adoption without taking the decision of other towns into account. General market access, without taking the telephone into account, represents such an effect. Stock effects take the already existing adoption in other towns into account, market access calculated based on the adoption and penetration in other towns is an example. Order effects shape the diffusion process by taking the whole diffusion pattern into account, a spatial interdependence between the adoption time is modeling such an effect. Next to market access, other town characteristics are also characterized and included to control for their influence on the diffusion and adoption processes.

Empirically this is tested with a study of the telephone diffusion in Bavaria. Munich, its capital, installed a local network exchange, the prerequisite for public use and private phone lines, in 1883. Over the next two decades the postal authority installed more than three hundred local exchanges in towns all over the state. Bavaria created a unified, statewide network relative soon

after the initial installation, connecting all local and regional networks within a decade (Bennett, 1895). Detailed information about the diffusion and adoption process in those two decades is combined with extensive information about the towns for the empirical analysis.

The historical setting and the technological diffusion of the telephone in the larger historical context are introduced in the next section leading into an explanation of the diffusion framework. After detailing the data the analysis begins with introducing the applied methodology. The first question about the diffusion over towns is answered with a duration model for the time frame 1883 until 1905, including time-varying covariates or spatial duration dependence. The second question utilizes a spatial autoregressive specification for cross-sectional data from the years 1896, 1900 and 1905. This is followed by a discussion about the quantification of the impact, market access is shown to have speed up diffusion over towns by about 3.5% while 4% of all lines in 1905 are due to the possibility to call subscribers in other towns.

2 Setting

2.1 Telephone

The telephone was the third revolutionary change in communication services during the 19th century. After the spread of the public mail system under the idea of universal access and the spread of electric communication technology through the introduction of the electric telegraph system the telephone represented another significant technological advance . Technological breakthroughs in 1876 allowed the commercialization of the idea of the telephone and by early 1878 the first public exchange was opened, which moved the technology beyond internal, private networks. The initial networks were pure hub and spoke systems, where an individual subscriber had to contact the central network exchange which then connected him to the desired recipient of the call. This system was then extended to allow for an additional connection between the network exchange of the call initiator and the exchange the call recipient was connected to (Kingsbury, 1915)

Countries all over the world started immediately to adopt this new communication method, London opened the first public exchange in Europe in 1878, Paris followed in 1879, and Berlin saw the establishment in 1881 (Bennett, 1895; Hesse, 2002). Although the American companies set up European subsidiaries to install public networks, some of the states refused to grant them the necessary permissions and gave their postal authorities a monopoly. This was also based on the initial perception, that the telephone was a technology to be used in combination with the telegraph rather than as an independent system (Wallsten, 2005).

2.2 Bavaria

Bavaria was one of the states that granted a monopoly for its public postal authority. It was a German state that had controlled its core territory for centuries and expanded to its contemporary borders in 1815. As a member of the Deutsche Bund, the political institution of German states, and the Zollverein, the customs union between a group of German States, it had close political and economic connections to its neighbouring states already prior to the founding of the empire in 1871. The state still had large rural areas, but a number of urban centers were strongly industrializing in the second half of the 19th century (von Waltershausen, 1920). When Bavaria surrendered its independence and agreed to join the new German Empire in 1871, it insisted on a number of rights to preserve a certain degree of autonomy within the new political structure. One of the most visible signs of this autonomy was the independent Postal service. While the services of the other states were merged to form the new Imperial Postal system the Bavarian Postal authority, as well as that of its neighbour Wuerttemberg, retained full autonomy (Bennett). This independence also included the telegraph. The services did cooperate very closely, one example was the German participation in the Universal Postal Union, which was handled by the Imperial Service. Close formal cooperation had already been introduced prior to the empire, most notably in the German Postal Union as well as the Telegraph Union, both established by 1850 (von Waltershausen, 1920). These created a single postal area in Germany and coordinated the telegraph systems.

As mentioned above, in Central Europe most telephone systems were introduced through the postal services, the emerging Bavarian telephone network was no exception.

In the case of network exchanges, the final decision whether a local network would be established in a particular town, was actually made by the Bavarian state government. The full process nevertheless did start in the towns itself. If there was noticeable demand for private telephone lives in a town, the local municipality had the option to submit a petition to the Bavarian Postal authority. Such a petition had to include the names and expected expenditure on the service of potential subscribers in that location. The authority collected the petitions and submitted them with a rough cost estimate to the government. Since the establishment of these exchanges was a major capital expense, the government had to submit a budget request to the parliament before it could authorize the postal authority to establish these networks. Parliamentary debates show that members of parliament were actively lobbying the government and the authority for priority treatment of locations in their constituencies . Once the government had received budgetary approval[1], the postal authority was tasked to create the exchanges (Thiel, 1983). Since the decision and the procurement process for technology was centralized it allows to focus the analysis on demand factors and remove the supply side of technology from consideration in this study.

The early adopters within towns were usually businesses, private households only rarely subscribed for a line. This is clearly visible in early phone books which indicate the nature of the business of each subscriber (und Telegraphen, 1905). A quantitative confirmation is provided byGünther (1910), who lists categories of subscribers for the town of Halle, which is not in Bavaria but should be quite comparable to Bavarian towns. The rate of purely private lines is 0.3%, though a large number of business customers might have used their lines for private calls, especially if the business premises and private rooms were in the same building.

[1] Approval was granted for a total sum of capital to be used for a certain number of projects over a number of years rather than individual projects (Thiel, 1983).

2.3 International diffusion

The introduction of a publicly accessible telephone network in Bavaria within a year of a similar start in the German empire implies that Bavaria was not leading technology adoption in Europe, but was also clearly not lagging far behind. A similar picture emerges for the rate of penetration. Figure 1 shows the number of phones per capita across a range of European countries for the years 1896, 1900 and 1906 , again Bavaria was not leading the pack but was doing comparatively well. Clearly leading the phone adoption in Europe and worldwide were the scandinavian countries, which saw substantially higher adoption than other European states. Bavaria trailed them together with the rest of the German Empire, Luxembourg and the United Kingdom. However the adoption rates in other rich European nations like France and the Netherlands did lag significantly behind Bavaria, while the southern and eastern periphery followed with a even more substantial distance.

Some of the reasons why Bavarians adopted relatively fast in comparison to other European states were the relatively low tariffs and fees as well as the monopoly regulation, which may have hindered adoption compared to countries with competitive markets but was more beneficial than strongly regulated private provision (Wallsten, 2005; Bennett, 1895; Günther, 1910).

3 Diffusion Framework

The analysis of diffusion processes usually focuses on the initial adoption and rate of adoption on a country or state level (Rogers, 1995). Alternatively, the diffusion is also analyzed with a focus on the decision of individual economic units, usually firms or households. Wallsten (2005) and Rammert (1990) examples for the first, Scott (2011) for the later. These two types neglect one important level, namely the spatial diffusion within a country. These internal, spatial characteristics of the diffusion process have implications for the speed of diffusion within the country as a whole and allow to investigate whether and why certain characteristics, for example market access, matter.

3.1 Technology diffusion

Figure 2 shows a map of all local exchanges established by 1905, while figure 3 presents the cumulative number of local exchanges over time, the pattern clearly showing the usual pattern of a logistic curve. Figure 4 shows the penetration rates in all towns in 1896, 1900 and 1905 plotted against the time phone service had been available in each case. The plot does show a slight upward trend but no clear pattern emerges. This is likely due to the longer time frame of diffusion in this case, the adoption rate will increase for more than half a century after the end of period under study, observations are likely therefore from the initial stage of the S-shaped pattern. One of the major approaches to explain diffusion patterns, and in particular the observed logistic curve, is the model by Karshenas and Stoneman (1993) which classifies explanatory effects into three different categories, namely rank, stock and order effects.

The first category, rank effects, contains town characteristics that influence the the adoption without taking the adoption status of other towns into account. The adoption status is made only with reference to particular town characteristics. An example is an adoption mechanism such that all towns with a size larger than a particular threshold receive an exchange. Towns grow over time, so more and more will cross the threshold over time. Depending on the underlying distribution of the characteristics this can explain the observed diffusion pattern.

The second category contains stock effects, which take the already existing adoption decisions about other towns into account. An example is an adoption mechanism that triggers an adoption when another town within a particular geographic distance has made a positive adoption decision. This behavior resembles an epidemic diffusion, though the particular transmission mechanism is strongly dependent on particular town characteristics.

The final category, order effects, describes effects which shape the diffusion process by taking the whole diffusion pattern into account. An example is an adoption mechanism based on the political orientation of a town. If the adoption simply follows the rank ordering of the election vote shares of a particular party, than the absolute share of the votes do not matter, only where the town is in

relationship to all other towns in the distribution.

The model is often applied to technology adoption for firms, however it is easy to adopt for the purpose here by substituting towns for firms. The existence of the two levels of diffusion, network exchanges and phone lines, can then be interpreted analogous to inter-firm and intra-firm diffusion (Galliano and Roux, 2008). While the adoption of the local exchanges follows clearly the usual pattern of a logistic curve the adoption of individual lines seemingly did not, at least is there no clear curve visible in figure 4 while shows the adoption rates plotted against length of service for the years of 1896, 1900 and 1905. This is however misleading, since the adoption process was barely starting at the time and did not finish till decades later (Scott, 2011) This implies that the adoption was still in the first part of the curve where only a small set of possible subscribers had made a positive adoption decision.

The existence of a monopoly provider with standardized procedures also implies that the process for potential subscribers to acquire a line is identical for all local networks. This implies that the supply side of the market in both cases, the adoption of local exchanges in towns and the adoption of phone lines within networks, is identical for all potential participants. This implies that there are no concerns about differential supply conditions affecting the adoption patterns.

The practical application of the framework will be detailed in the following section, which introduces the data used in the empirical analysis and classifies the associated effects according to this framework.

4 Data

The empirical use of this framework requires data about the diffusion processes, in particular the date of establishment of local exchange networks in towns as well as the number of lines within towns. Furthermore factors, categorized into the rank, stock and order framework, that influence the establishment and uptake of the telephone are included.

4.1 Outcome Data

The establishment of a new local exchange, which is the condition for the installation of private lines, is measured by the date of its official data of commissioning into service. Although this doesn't precisely follow the timing of the adoption decision by the central authority, for example due to geographic conditions local networks might have had different construction spans, the main point in time when the telephone begins to have an effect is obviously the date at which phone calls could actually be made throughout the local network. The postal authority in its annual reports list the opening days of new exchanges, which provides the data for 306 exchanges opened in towns between 1882 and the end of 1905 (und Telegraphenverwaltung, 1905).

The adoption within towns is measured by the number of phone lines. A number of the annual reports do list the number of phone lines for each individual local network. The number consists of all private subscriptions, lines by administrative and other government institutions as well as public phones. The analysis makes use of the data reported for the years of 1896, 1900 and 1905.

4.2 Market Access

The main hypothesis to be tested is the role of market access in the adoption processes. Market access consists of two components, the size of a market and the spatial transaction costs to trade in this particular market. The transaction costs are usually proxied by the distance between the two markets (Fujita et al., 1999). Since the number of calls between two locations decays approximately with distance squared (Ploeckl, 2011) I use this relationship for the empirical calculation of market access. This distance is measured as great circle distance between any pair of towns. This is based on the definition of each town as a separate market. The size of these markets is measured in two distinct ways. The first measure is the number of inhabitants, the population size of the town. This is the standard measure used in the economic geography literature (Ploeckl, 2010). The second measure is the number of phone lines active in the local exchange network. This is obviously highly time variant and also only applicable to towns where a local exchange has already been established. This distinction

between the two measures also implies that market access based on population numbers are rank effects, since they do not depend on the adoption decision in any location. Market access based on subscriber lines is however a stock effect since there the adoption decision in other towns is obviously highly relevant.

The impact of the telephone is however not unidirectional, but it changes transaction costs in both directions. This is relevant since a town not only has market access in other towns but also represents market access for other towns. The adoption decision for a particular location might therefore depend not only on the markets that can be access from this location but also the size of market access this particular town represents. To distinguish this idea from market access introduced above I refer to it as market size.

4.3 Controls

Next to market access a number of other factors potentially influence the adoption decisions and can create the observed diffusion patterns. The following section describes town characteristics that are used to control for these factors, in particular economic and political ones.[2] The data is based on a number of different organizational units. A number of general as well as economic characteristics are directly based on the town level itself, respective the formal municipalities. The next administrative level, and organizational unit for data, is the *Bezirk*. This county unit takes two forms, first a number of the larger towns are *kreisfrei*, meaning that the municipality is at the same time a county as well, and second *Landkreise*, regular counties usually labeled after the seat of the county administration. There are 155 counties used in the analysis. The third utilized units are constituencies, in particular the 42 districts for the *Reichstag* elections. These are obviously predominantly used for the political control factors.

4.3.1 Rank Effects

The first group of control variables are those characterized as rank effects. This implies that if these variables are shown to have an influence, only the value of the town itself matters, not that in other places.

[2] Table 1 reports summary statistics for these variables.

Included are standard town characteristics, namely the population size of the town, its administrative role and relative geographic position. The first is based on census numbers recorded every five years, the second contains a dummy that indicates whether a town was the seat of county administration. Usually the town formed a county together with the area around it, however as mentioned in the case of some important, and usually larger, towns, the town itself was equivalent to the county. Next to this dummy I include a variable indicating how much of the county population lives in a particular, indicating the relative importance of the town for the particular region. In some cases cities that represent also counties were separately also the seat of the administration for the rural county around it. I include a dummy which indicates whether a town was in such a rural county, indicating that it was in the vicinity of a major city. Additionally I include a dummy that indicates whether a town is close to the state border, which is indicated if the county shares part of the state border.

The next set of variables contains information about the economic structure of the town. The first is the share of the primary sector in male occupation, the percentage of men active in agriculture. This information is based on numbers for the sectoral composition of constituencies in 1895. The second is related to this by containing the share of the total population engaged in non-farm employment at the district level, capturing not only the non-agricultural part but also the total employment in the district. This data is available for 1882, 1895 and 1907. The third variable in this set uses the occupational categories of non-farm employment to create an indication of specialization in the district. The Bavarian statistics report the number of workers in 23 separate categories, the variable is then an indication of how strong an individual district deviates in its occupational structure from the statewide average. This is calculated with the formula $\frac{1}{2}\sum_{i=1}^{N}|\frac{sec_{iC}}{emp_C} - \frac{sec_{iB}}{emp_B}|$ where i indexes the sector, B the whole of Bavaria and C the district in question.

Two more economic variables are information about the tax revenues and structure in the districts. The first is the per capita revenue of state taxes in each district in 1887, indicating the amount of economic activity in the region. The second is the height of the *Gemeindeumlage*, a municipal tax rate specified as a share of state taxes. Municipalities have the power to set this rate individually

to fulfill their obligations. If other sources of funding were available, this rate could drop to zero. The variable is the average rate by district in 1887.

The above set of economic characteristics indicates the general structure, the next set is directly related to trade and transportation. The first variable is a dummy that indicates whether the town in question had a railroad station in 1882. The second variable measures the importance of the rail access, it contains the per capita revenue received at that particular station in 1882. The final railroad variable indicates the per capital difference in freight sent and received at the station measured in per capita terms. All three variables are based on statistical information from public railway authorities.

The final set of rank order characteristics concerns the direct demand for communications services. In particular it contains the per capita revenue from all other postal services, including mail and telegraph provision. The data for the year 1882 is taken from the annual statistics of the postal authorities.

4.3.2 Stock Effects

The second category of controls, stock effects which take the positive adoption decisions by other into account , is quite small. As described above market access calculated with the number of lines does fall into this category. Another included control is the split of phone lines according to the type of participants. Since it involves information about the adoption within towns, the variable is only relevant for the analysis of diffusion of the phone within towns rather than the diffusion of network exchanges. The variable is based on information about the ownership of phone lines, in particular it splits the total number of lines into three categories, lines owned by private subscribers, by public institutions and public phones, open to use by the general public. The variables are specified as the share of government respective public access phones of the total lines in town.

4.3.3 Order Effects

The final category of controls are order effects, which take the whole distribution into account. In particular these are political variables as well as a connection to religion. The first variable doesn't look at the influence of individual political

movements but the general political engagement of a location. This is measured with the level of participation in the federal elections of 1890, again measured on a electoral district level.

Although Bavaria is one of the traditionally catholic states in Germany, its territorial expansion, especially during mediatization and the Napoleonic wars at the turn of the 19th century, meant that it had a substantial protestant minority. The possible influence of religion is made more implicit through a link with political indicators. The *Zentrum* party was the main party for catholic interests and a strong political force. I use the relationship between the catholic population share and the *Zentrum* vote share to determine whether the possible effect was due to religion directly or due to its political influence. The variables are specified as the vote share of the Zentrum party in the 1890 election as well as the difference between the *Zentrum* vote share and the catholic population share in 1890 on a electoral district level.

Besides the conservative catholic party there are a number of other political forces, in particular liberal parties as well as socialists. The variables are again specified as their vote shares in the 1890 elections.

5 Analysis

The empirical analysis is conducted separately for the two diffusion process. The first, the diffusion of local exchange networks over towns, is conducted with a duration analysis approach. The town penetration rates are then analyzed with a cross-sectional analysis utilizing an spatial econometrics approach.

5.1 Adoption of Networks

As demonstrated above, the diffusion of local network exchanges was not instantaneous but progressed over more than two decades. The main question is therefore what factors determined when a town was selected as a site. This leads to an empirical approach that focuses on the timing of these events, which implies the appropriateness of a duration analysis approach. These methods are also known as survival analysis indicating the focus on analyzing the length of a time spell until a particular event, often referred to as *failure* or *death*, hap-

pens. In this case the *failure* is the opening of a newly installed local network exchange (Kalbfleisch and Prentice, 1980).

This approach therefore includes a discrete choice outcome with a binary status, zero if failure has not happened yet and one if it does occur. Furthermore the probability of failure at any given time is modeled, the resulting distribution over time is referred to as the hazard rate. One formalization of this hazard rate is to use a parametric approach, in particular I use the Weibull distribution to formally model the hazard rate. This implies that this rate can be written as :

$$h(t) = pt^{p-1}[exp(x(t)'\beta]$$

where t is time, x a set of covariates, p a parameter of the underlying distribution and β a vector of parameters for the influence of covariates on the hazard rate. p and β will be estimated empirically. The parameter p determines the shape of the hazard rate, if $p > 1$ the rate increases over time, $p = 1$ implies a constant rate while $p < 1$ implies a decreasing rate. The underlying assumption of the baseline specification is the same base hazard rate, as represented in the parameter p, for all towns, regardless of region or other characteristics. The only differentiation is the influence of town-specific covariates. The next specification modifies this to take regions into account through a stratification of the specification. This implies that the hazard rate parameter will be identical for all towns within the same region but does vary between regions. I use the seven Bavarian *Regierungsbezirke* in this stratification. The covariates, $x(t)$, can be time-varying, though some specifications will use only time-invariant ones. The vector of parameters β expresses how the covariates affect the hazard rate. If the covariates are time-invariant their effect on the hazard rate has the same proportional multiplicative effect at any given time of observation. If the covariates vary, the effect obviously varies with them.

Table 2 shows the first set of results. Column 1 displays the results for the baseline regression with time-invariant covariates. Column 2 displays the results when regional effects are included and column 3 shows the results for the inclusion of time-variant covariates. The results correspond quite well between the three specifications. The results show that market access had an impact and

that the diffusion follows economic criteria, larger towns as well as those with a higher employment ratio and higher postal revenues received exchanges faster As expected the larger a town is in 1880 the faster it received a local network exchange. This effect remains pretty much the same when population is entered as a time-variant variable, again the larger the town the faster the adoption. Since the outcome variable is constant but the magnitude of the covariate increases is there a minor decrease in the size of the coefficient. From the set of economic control variables the employment ratio, the share of non-agricultural workers in the total population has an impact on the adoption decision. The larger this share the faster the town received a local exchange. This impact confirms that initial adoption was driven strongly by business. As has been shown above, the vast majority of early adopters were not individual households but businesses. This is also strongly confirmed by the significance of the local postal revenues. The resulting coefficients demonstrate demonstrate that a comparatively higher use of mail and telegraph lead to a faster establishment of a local exchange. A higher demand for postal communication services like mail and telegraph points strongly to a higher demand for telephone services as well. This implies that it was easier in these towns to find business interested in subscribing, the prerequisite for a successful application for an exchange. The results also indicate that the process did not have a strong political bent, the coefficients on the political variable are statistically insignificant. This implies that the spatial diffusion of the telephone was a process governed by economic consideration, political forces did not substantially shape it. This points towards a relative independence of the postal authority within Bavaria.

The main question of interest however is the effect of market access. All three specifications demonstrate that some form of market access matters for the diffusion of information technology. The direction of the effect is as expected, locations with a larger market access receive a local exchange faster. More ambiguous however is which form of market access actually matters. The first two specifications contain only market access measures derived with town population. In both cases it is market access, the size of the market accessible from the town in question, that seems to matter for the adoption decision, while market size, the measure of how much market access this town represents

for others, is not statistically significant. The third specification contains both, market access measures derived with population as well as those derived with the extent of phone adoption within existing local exchanges. The results depicted in column 3 indicate that is not the general market but the specific market measure that matters. The conclusion from this result is that the observed effect of market access is transmitted through a network effect rather than through a general effect on adoption. This shows that the effect is more likely a stock effect rather than a rank effect, the existing adoption decisions matter more than this particular town characteristic itself for the diffusion. This is confirmed by the result that it is specific market size rather than market access that influence the decision. The above described impact of economic characteristics indicate that demand in the town itself influenced the adoption process, this market size result complements this with the impact of the demand in towns which already had an exchange for extension of the network. The adoption decision is influenced not only by demand in the town in question itself but also by demand in other towns for new communications possibility with that particular town.

Another possibility for the observed result is simply an expansion of the network based on geography rather than market access. The introduction of a spatial correlation between closeby towns into the specification models this geographic effects.Kachi and Hays (2011) develops a new method to include this spatial effect in the estimation of an accelerated failure time model with a maximum likelihood approach. The formal specification to be estimated is $y = Ay + X\beta + Lu$, where y is the outcome, A is the matrix modeling the spatial dependency, X the set of covariates and L a correction necessary in connection with the error terms u.

For technical reason only general market access and market size can be included, though different possible geographic patterns can be tested. In particular three patterns are tested. The first, labeled decay, assumes that towns are influenced by all other towns, but closer towns have a stronger impact. The spatial correlation is therefore modeled with a commonly used distance decay function, more precisely inverse squared distance. The second, labeled band, assumes that towns are influenced by towns within a particular distance threshold and that the influence of these towns is identical. The correlation is modeled

with dummies indicating whether the distance between two towns is below a distance threshold of 25km. The third, labeled region, is based on the development of regional phone networks. The tariff structure of the Postal authority grouped local exchanges into *Bezirke*, usually spatially consistent regions, allowing for a particular rate structure within these groups. The particular shape of the groups is due to the historical development of the general network, local exchanges within this groups were often connected with each other before links with the state-wide network were made. Again the correlation is modeled with a dummy indicating that two towns are within the same group.

The results for the three different spatial correlation models are reported in table 3. The results for the control variables are pretty much identical to the models without spatial correlation. In case of the market access variables and the spatial effect, the results indicate that it is indeed market access rather than a simple geographic network extension that drives the diffusion of exchanges over towns.

5.2 Adoption of Telephone Lines

The adoption of the telephone by private persons requires two steps, first the establishment of local network exchanges and second the decision by firms and households to subscribe to the service. The previous section has demonstrated the factors behind the first step, the establishment of local network exchanges. This section looks at the second step, the adoption by households and firms. The focus is again on the impact of market access on the adoption decision. In this step this explicitly equals network effects, not only local but also regional ones. In particular this analyzes whether the ability to make a call to a line of a different local exchange increases the number of subscribers. Additionally the local effect is investigated by determining whether local characteristics, in particular the population size of the town, affect the rate of adoption within the town.

The data are available as cross-sectional adoption rates for three different years, 1896,1900 and 1905. While above the temporal development was included through the parametric shape of the specification this has to be done differently

given this structure of the data. Here a time variable is included as an explanatory variable. Since the adoption rate figure shown above indicates that the process is still in an early phase the underlying curve is still rather linear in its shape and the included time measure is therefore simply specified as the number of months since the establishment of the local exchange.

The cross-sectional nature of the data and the incorporation of external network effects point towards the use of a spatial econometric approach, in particular a spatial lag model. This model uses a spatial autoregressive approach which requires to model the relationship between the observations directly with a spatial weights matrix. The specification is then conducted with a Maximum Likelihood estimation. Formally the specification is

$$y = \rho W y + X\beta + \epsilon$$

where y is the number of lines in local networks, W the spatial weight matrix and X is a set of covariates that potentially influence the phone lines uptake within towns. ρ and β are the coefficients to be estimated. The adoption rate is usually expressed as the number of lines per capita, this specification however uses the absolute number of lines as outcome variable. This is due to the nature of the spatial interaction between the observations, which models the influence of lines in other towns on the number of lines in each town. The effect of the spatial lag variable is additive, the total effect therefore the weighted sum of the effects of each individual town. To correct for this with regard to the influence of other explanatory factors I do interact all control variables with the relevant population size with the consequence that the resulting coefficients actually do show the impact on the adoption rate rather than the total number of lines.

Table 4 reports the results for the three year 1896, 1900, 1905. However the results for 1896 are likely not fully reliable due to the small number of observations relative to the number of explanatory factors. Nevertheless if the results are taken as an indication the effect of market access seems to correspond to this shown for 1900. Focusing on the results for 1900 and 1905 a particular pattern for the impact of market access emerges. As mentioned the specifications include market access in its general form as well as based on telephone lines

in the form of the spatial effect. The numbers indicate a shift from general market access, in particular market size though market access also is barely above statistical significance at 10% level, to specific market access, as modeled in the spatial network effect. So while the initial adoption is influenced by the size of the markets which can now be reached through the telephone this changes over time to a more network-like effect, where the number of subscribers begins to matter.

A shift in the patterns is also visible for some, though not all, covariates. There is no statistical evidence for a general time trend, the effect of time since installation seems to be substantially overshadowed by the impact of other covariates. Population however does prima facie exhibt a change in pattern, while it has an impact in 1900 where larger towns have a higher penetration rate, the effect is no longer statistically significant in 1905, indicating that the size of location no longer affects the speed of adoption. The effect of other town characteristics, in particular its administrative function and geographic position do not change, though there is a difference in significance between them. While the administrative function had no general influence the relative geographic position had. In particular towns close to borders appear to adopt towns faster. A potential explanation for this phenomenon is a spatial effect of towns across the borders since the Bavarian network was at least partially integrated those of neighbouring regions, in particular the rest of the German empire. The non-effect of administrative function is explained by the impact of the structure of subscribers. The shares of governmental as well as public lines have a statistically significant, negative impact on the rate of adoption. The more adoption is drived by non-private subscribers, the slower it is. Future research has to clarify whether this is really an effect of bureacuracy, a time-trend due to a initally higher, but upwards bounded adoption by public institutions. Similarly the impact of economic variables like employment share, agriculture, specialization and the two tax measures are changing between the two time points but without a clar pattern to what is driving these changes. The impact of transportation stays constant, towns without a railroad adopting faster, likely compensating for the absence of railroads, while those towns whose railroad stations have higher revenues are also adopting faster, indicating a complemen-

tarity between information and transportation. The same holds for the impact of other postal revenues, towns with a higher demand for mail and telegraph also exhibit a higher demand for phone lines as indicated by a higher adoption rate. In contrast to the adoption of local exchanges political variables exhibit a statically significant effect on the adoption rate. Again the pattern changes over time without a clear sense of what is driving these changes, though assuming that political ideology is correlated with other cultural differences the results do indicate that the adoption of individual phone lines might not be a purely economical decision.

There are two caveats about the discussion of these effects, in particular those with a changing pattern. First the statistical tests only look at significance in two cross-sections, future research will investigate more closely whether the change in impact itself is statistically significant. Second and more importantly, the sample for 1905 is considerably larger than that for 1900, since the number of installed local networks increased from 126 to 306. The results at the moment do not distinguish whether the change in effect is general, i.e. it holds for the full sample, or whether this is a compositional effect, i.e the change in effect is drived by a differential effect for those towns with newly established exchanges. Again this will be adressed in future research.

5.3 Impact

In the two previous section the results demonstrated that the existence of a network beyond the local exchange mattered for the extension of the network and the adoption of phone lines within towns. Here the magnitude of these effects is discussed. In a first step the effect of market access on the adoption of local network exchanges is quantified. Using the variable values and the coefficients of the main specification without time-varying effects implies the following impact. The average time to establishment is reduced by 3.5% while the median is 2.9%. This is effectively calculated without Munich since the establishment date of this exchange starts the process and is therefore essentially zero. This however should not change the picture in a significant way, since Munich is large enough that the adoption decision is likely much more driven by its sheer

size rather than the impact of a connection with other towns. Quantifying this impact in terms of time implies that the total time to adoption by all towns is reduced from 68400 to 66064 months, a reduction of about 150 exchange years. This implies that every exchange is installed about half a year earlier due to market access.

The specification used to estimate the impact on the adoption rate within towns is designed for an easy quantification of this effect. The additive nature of the spatial effect variable and the use of absolute lines as outcome variables imply that the product of the estimated coefficient with the spatial variable value results in the number of lines due to the network outside of the town. A comparison with the number of total lines shows then what share of the lines is due to this effect. Making this calculations for 1905 shows the following picture: The share of lines due to the wider network ranges from 0.002% to 401.4% with a mean of 25.8% and a median of 13.3%. The difference between median and mean and most importantly the upper end of the range indicate one particular problem with this calculation. The linear nature of the spatial effect implies that it is not implicitly bounded by the actual limit, which is 100% and every line is adopted because of the opportunity to call somebody outside the town. The towns with these high values are usually located in the vicinity of large towns, in particular Munich, where the high absolute number of lines simply drives the implied effect way above the numbers lines actually adopted in these smaller places. Computing the same statistics when the maximum is restricted to 100% does not substantially change the magnitude of the effect, indicating that is concentrated in only a few towns. The second calculation is then to derive the actual number of phones statewide due to this effect. While the shown average is unweighted by the size of the town, this calculation now uses the total number of lines as weights. As a result the share of lines due to wider network effect is about 4% of total lines. This sharp drop indicates that the network effects are more important for smallplaces than they are for larger places. This is also illustrated when Munich is dropped from the sample, which immediately raises the share up to 6%.

6 Conclusion

The progress of technology through new inventions and the improvement of existing ones influences the location of economic activity. Its impact on communication and transportation affects how firms and people structure their life and business spatially. This paper demonstrates with a historic case study that there is also a reverse effect, market access and the underlying existing spatial distribution of economics activity does influence the diffusion pattern of technology. Furthermore it shows that the spatial diffusion was clearly a predominantly economic process without undue political modifications. The adoption of individiual lines within towns however did depend not only the towns' economic characteristics but also their political ones.

Telecommunications like the telephone are an obvious candidate regarding a potential influence of market access. Its nature as a networking technology implies that the potential set of links will influence how the network expands and new locations will be integrated, as this study demonstrates. This raises the question how general this effect is and whether it extends beyond clear network industries. Possible next steps is to look into the diffusion of transportation technology and the development of infrastructure.

This study does quantify the impact of market access, but this also points towards the use of these results to derive not only the technical but also the welfare impact of technology and market access. In particular the approach of social savings seems to be fruitful avenue for future research, however the main obstacles which has to be overcome is the nature of pricing and market structure. The absence of a competitive market and the highly regulated, exogeneously fixed pricing implies that any research in this direction needs to derive the benefit of phone calls direction rather than through the use of price and quantity.

The telephone was a technological breakthrough that changed communications for good. The introduction of true interactive conversation shaped how businesses, governments and individuals dealt with the existing spatial distribution of economic and other activity. This study demonstrates that this technology however was not just a force that shaped this distribution, it was also strongly influenced by the existing conditions under which it diffused over space.

References

Bennett, A. R. 1895. *The Telephone Systems of the Continent of Europe.* Longmans, Green.

Chandler, Alfred D. 1977. *The Visible Hand: The Managerial Revolution in American Business.* Harvard University Press, Cambridge, Mass.

Fujita, M., P. R Krugman, A. Venables, and Inc Ebrary. 1999. *The spatial economy: cities, regions and international trade.* Vol. 19991, Wiley Online Library.

Galliano, D., and P. Roux. 2008. "Organisational motives and spatial effects in Internet adoption and intensity of use: evidence from French industrial firms." *The Annals of regional science*, 42(2): 425–448.

Günther, E. 1910. *Die europäischen Fernsprechgebührentarife, ihre Grundlagen, Entwickelung und zweckmässige Gestaltung.* Vol. 61, G. Fischer.

Hesse, J. O. 2002. *Im Netz der Kommunikation: Die Reichs-Post und Telegraphenverwaltung, 1876-1914.* Vol. 8 of *Schriftenreihe zur Zeitschrift fuer Unternehmensgeschichte*, CH Beck.

Kachi, A., and J.C. Hays. 2011. "Interdependent Duration Models in Political Science."

Kalbfleisch, J. D., and R. L. Prentice. 1980. "The statistical analysis of time failure data." *The statistical analysis of time failure data.*

Karshenas, M., and P. L Stoneman. 1993. "Rank, stock, order, and epidemic effects in the diffusion of new process technologies: An empirical model." *The RAND Journal of Economics*, 503–528.

Kingsbury, J. E. 1915. *The telephone and telephone exchanges: their invention and development.* Longmans, Green, and Co.

Landesamt, Bayerisches Statistisches. 1892. "Influenza-Epidemie des Jahres 1889/90 im Königreiche Bayern. Enthält außerdem: Aktiv-Vermögen, Schulden und Umlagen der bayerischen Gemeinden." 57.

Landesamt, Bayerisches Statistisches. 1911. "Gewerbe und Handel in Bayern." 82.

Landesamt, Bayerisches Statistisches. 1954. "Historisches Gemeindeverzeichnis; Die Einwohnerzahlen der Gemeinden Bayerns in der Zeit von 1840 bis 1952." 192.

Ploeckl, F. 2010. "Borders, market access and urban growth; the case of Saxon towns and the Zollverein." *Documents de treball IEB*, , (42): 1–65.

Ploeckl, Florian. 2011. "The Local Gravity of Information."

Rammert, W. 1990. "Telefon und Kommunikationskultur: Akzeptanz und Diffusion einer Technik im Vier-Länder-Vergleich." *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, 42(1): 20–40.

Reibel, C. W. 2007. *Handbuch der Reichstagswahlen 1890-1918: Bündnisse, Ergebnisse, Kandidaten.* Vol. 1, Droste.

Rogers, E. M. 1995. *Diffusion of innovations.* Free Pr.

Scott, P. 2011. "Still a niche communications medium: The diffusion and uses of the telephone system in interwar Britain." *Business History*, 53(6): 801–820.

Thiel, H. 1983. *100 Jahre Telefon in Bayern.* Nuernberg:Oberpostdirektion Nuernberg.

und Telegraphen, Königlich Bayerische Posten. 1905. *Amtliches Verzeichnis der Teilnehmer an den Ortstelephonnetzen München, Ismaning, Pasing und Planegg.* Munich:Huber.

und Telegraphenverwaltung, Königlich Bayerische Post. 1905. *Statistischer Bericht ueber den Betrieb der Koeniglich Bayerischen Posten und Telegraphen.* Munich.

Verkehrsansalten, Königlich Bayerische. 1882. *Statistischer Bericht ueber den Betrieb der Koeniglich Bayerischen Verkehrs-Anstalten.* Munich.

von Waltershausen, A. S. 1920. *Deutsche Wirtschaftsgeschichte, 1815-1914.* G. Fischer.

Wallsten, S. 2005. "Returning to Victorian Competition, Ownership, and Regulation: An Empirical Study of European Telecommunications at the Turn of the Twentieth Century." *Journal of Economic History*, 65(3): 693.

7 Appendix

The following table gives an overview about the sources for all data sets.

Data	Year	Source
Town Population	1880-1905	Gemeindeverzeichnis
Town Status	1880	Gemeindeverzeichnis
County Population	1880	Gemeindeverzeichnis
County Location	1880	Gemeindeverzeichnis
Agricultural Employment Share	1890	Reibel
Employment Ratio	1882, 1895, 1907	Gewerbe
Sectoral employment	1882, 1895, 1907	Gewerbe
State Tax	1887	Beitraege 57
Local Tax	1887	Beitraege 57
Railroads	1882	Verkehr
Postal revenues	1882	Verkehr
Election Participation	1890	Reibel
Vote Shares	1890	Reibel
Catholic Population Share	1890	Reibel

Gemeindeverzeichnis refers to (Landesamt, 1954)

Reibel refers to (Reibel, 2007)

Gewerbe refers to (Landesamt, 1911)

Beitraege 57 refers to (Landesamt, 1892)

Verkehr refers to (Verkehrsansalten, 1882)

8 Tables

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.
Market Access 1880	325.731	262.668	58.14	2539.205
Market Size 1880	329.387	1116.72	12.783	14038.053
Population 1880	4340.725	13684.93	158	195839
Town Status	0.17	0.376	0	1
County Population Share	0.181	0.303	0.006	1.081
Fringe Region	0.275	0.447	0	1
Border Region	0.448	0.498	0	1
Agriculture	62.331	15.506	2.2	78.600
Employment Ratio 1882	0.127	0.065	0.054	0.693
Specialization 1882	0.264	0.086	0.134	0.647
State Tax	4.697	2.294	1.899	31.178
Local Tax	2.866	1.971	0	22.257
Railroad Station	0.601	0.49	0	1
Railroad Revenues	28.315	79.353	-4.353	889.690
Railroad volume	0.012	6.487	-88.208	46.487
Postal Revenues	4.288	2.556	0	20.284
Election Participation	58.913	11.088	32.7	81.400
Zentrum Vote Share	59.933	29.556	0.1	98.7
Zentrum vs Catholic	16.551	12.18	0.700	59.5
Liberal Vote Share	28.031	27.173	0	95.8
Socialist Vote Share	8.755	11.885	0.4	56.4
N		306		

Table 2: Diffusion of local exchanges

	Baseline	Stratified	Time-varying
_t			
Market Access 1880	-0.000140***	-0.000110**	-0.0000777
	(-3.44)	(-2.76)	(-1.21)
Market Size 1880	0.0000146	0.0000120	0.0000253
	(0.63)	(0.34)	(0.65)
Population 1880	-0.0000165***	-0.0000165***	
	(-8.39)	(-5.92)	
Town Status	-0.00824	-0.00794	0.00402
	(-0.30)	(-0.26)	(0.07)
County Population Share	-0.0513	-0.0973*	-0.0514
	(-1.12)	(-2.17)	(-0.66)
Fringe Region	-0.00993	-0.0129	-0.0410
	(-0.67)	(-0.82)	(-1.71)
Border Region	-0.0226	-0.0230	-0.0359
	(-1.69)	(-1.49)	(-1.39)
Agriculture	0.000887	0.000434	0.000630
	(0.82)	(0.33)	(0.34)
Employment Ratio 1882	-0.766**	-0.672*	-1.096**
	(-3.04)	(-2.50)	(-2.89)
Specialization 1882	0.0132	0.103	0.0773
	(0.11)	(0.80)	(0.44)
Statet Tax	0.00919	0.00643	0.0153
	(1.72)	(0.96)	(1.84)
Local Tax	-0.0150	-0.0124	-0.0263*
	(-1.82)	(-1.37)	(-2.30)
Railraod Station	-0.00653	-0.00971	-0.00806
	(-0.43)	(-0.57)	(-0.33)
Railroad Revenues	0.00000315	0.00000682	0.0000953
	(0.02)	(0.05)	(0.50)
Railroad volume	0.00104	0.00105	0.00238
	(0.72)	(0.87)	(1.56)
Postal Revenues	-0.0191***	-0.0170***	-0.0263***
	(-5.74)	(-4.53)	(-4.72)
Election Participation	0.00114	0.000728	0.00142
	(1.47)	(0.63)	(0.82)
Zentrum Vote Share	-0.0000312	-0.000297	0.000253
	(-0.05)	(-0.34)	(0.20)
Zentrum vs Catholic	-0.000876	-0.00169	-0.00145
	(-1.25)	(-1.59)	(-0.95)
Liberal Vote Share	-0.000658	-0.00146	-0.00137
	(-1.14)	(-1.80)	(-1.26)
Socialist Vote Share	0.000347	-0.0000297	0.000702
	(0.26)	(-0.02)	(0.29)
MarketAccess			-0.000214
			(-1.31)
MarketSize			-0.0000227**
			(-3.27)
Population			-0.0000150***
			(-5.02)
Constant	5.624***	5.721***	5.850***
	(39.54)	(33.13)	(23.16)
ln_p			
Constant	2.177***	1.830***	1.686***
	(36.57)	(7.98)	(8.21)
Regional effects	No	Yes	Yes
Observations	306	306	66064

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Diffusion of Local Exchanges with Spatial Correlation

	Decay	Band	Region
mu			
Market Access 1880	-0.000117*	-0.000135***	-0.000130***
	(-2.43)	(-3.67)	(-3.59)
Market Size 1880	0.0000150	0.0000141	0.00000942
	(0.49)	(0.45)	(0.32)
Population 1880	-0.0000165***	-0.0000166***	-0.0000165***
	(-6.63)	(-6.55)	(-6.87)
Town Status	-0.00860	-0.00895	-0.0192
	(-0.24)	(-0.26)	(-0.54)
County Population Share	-0.0541	-0.0566	-0.0604
	(-1.11)	(-1.15)	(-1.25)
Fringe Region	-0.00991	-0.00931	-0.00774
	(-0.55)	(-0.52)	(-0.43)
Border Region	-0.0212	-0.0241	-0.0226
	(-1.34)	(-1.52)	(-1.45)
Agriculture	0.000924	0.00104	0.000462
	(0.84)	(0.93)	(0.41)
Employment Ratio 1882	-0.744**	-0.705*	-0.596*
	(-2.70)	(-2.44)	(-2.03)
Specialization 1882	0.0124	0.00523	-0.0165
	(0.09)	(0.04)	(-0.13)
State Tax	0.00917	0.00887	0.00966
	(1.51)	(1.46)	(1.60)
Local Tax	-0.0151	-0.0148	-0.0155*
	(-1.95)	(-1.92)	(-2.00)
Railroad Station	-0.00788	-0.00714	-0.00525
	(-0.47)	(-0.43)	(-0.32)
Railroad Revenues	0.00000108	0.00000466	-0.00000832
	(0.01)	(0.03)	(-0.06)
Railroad volume	0.00102	0.00105	0.000909
	(0.75)	(0.77)	(0.68)
Postal Revenues	-0.0193***	-0.0193***	-0.0183***
	(-5.93)	(-5.97)	(-5.66)
Election Participation	0.00125	0.00120	0.000775
	(1.39)	(1.35)	(0.85)
Zentrum Vote Share	-0.000122	-0.000125	-0.0000618
	(-0.17)	(-0.17)	(-0.09)
Zentrum vs Catholic	-0.000925	-0.000896	-0.000862
	(-1.14)	(-1.10)	(-1.09)
Liberal Vote Share	-0.000723	-0.000675	-0.000938
	(-1.04)	(-0.98)	(-1.32)
Socialist Vote Share	0.000424	0.000531	-0.000177
	(0.27)	(0.34)	(-0.11)
Constant	5.185***	5.270***	5.719***
	(8.01)	(9.79)	(35.04)
rho			
Constant	0.0807	0.0645	-0.000199
	(0.70)	(0.69)	(-1.60)
lambda			
Constant	8.819***	8.831***	8.891***
	(21.60)	(21.57)	(21.46)
Observations	306	306	306

t statistics in parentheses

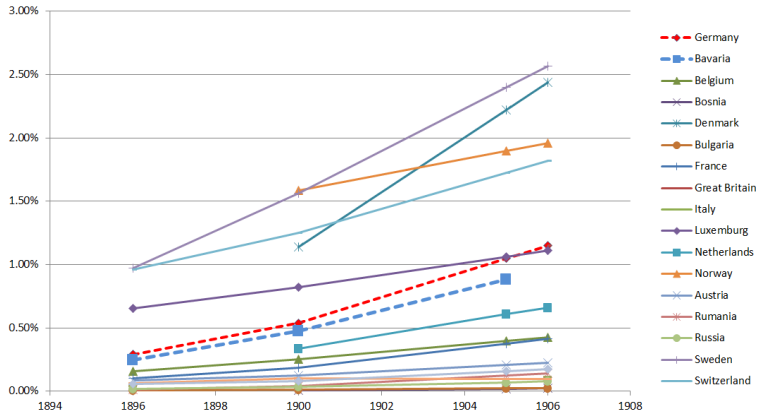
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Adoption of Telephone within Towns

	Year 1896		Year 1900		Year 1905	
Variable	Estimate	p-Value	Estimate	p-Value	Estimate	p-Value
Constant	0.03637	0.00	0.02303	0.00	0.01749	0.02
Installation Length	-0.00003	0.00	0.00000	0.85	-0.00001	0.15
Market Access 1880	0.00000	0.00	0.00000	0.11	0.00000	0.16
Market Size 1880	0.00000	0.00	0.00000	0.01	0.00000	0.10
Population	0.00000	0.00	0.00000	0.00	0.00000	0.54
City	-0.00431	0.00	0.00088	0.52	-0.00039	0.79
Population Share	0.00306	0.00	-0.00155	0.33	0.00137	0.41
Fringe	-0.00298	0.04	-0.00112	0.32	0.00053	0.68
Border	0.00191	0.00	0.00180	0.00	0.00193	0.00
Government Share	-0.01243	0.00	-0.00779	0.00	-0.01995	0.00
Public Share	-0.01754	0.01	-0.01340	0.00	-0.01500	0.00
Agriculture	-0.00012	0.00	-0.00002	0.63	0.00011	0.01
Employment Ratio	-0.01765	0.00	-0.00148	0.37	-0.00829	0.04
Specialization	-0.01519	0.00	-0.00818	0.02	0.00303	0.54
State Tax	0.00023	0.09	0.00048	0.00	0.00035	0.14
Local Tax	0.00009	0.42	0.00017	0.25	0.00049	0.01
Railroad Station	-0.00028	0.83	-0.00450	0.00	-0.00371	0.00
Railroad Revenues	0.00001	0.00	0.00001	0.00	0.00001	0.00
Railroad Volume	0.00028	0.19	0.00023	0.11	0.00009	0.28
Postal Revenues	0.00064	0.00	0.00046	0.00	0.00164	0.00
Election Participation	0.00013	0.02	-0.00001	0.82	-0.00016	0.00
Zentrum	-0.00020	0.00	-0.00012	0.00	-0.00008	0.02
Catholics - Zentrum	-0.00015	0.00	-0.00006	0.02	0.00004	0.24
Liberal	-0.00022	0.00	-0.00011	0.00	-0.00002	0.54
Socialist	-0.00016	0.00	0.00002	0.68	0.00002	0.62
Spatial Effect	0.15019	0.56	0.16827	0.15	0.48795	0.00
Observations	38		126		306	

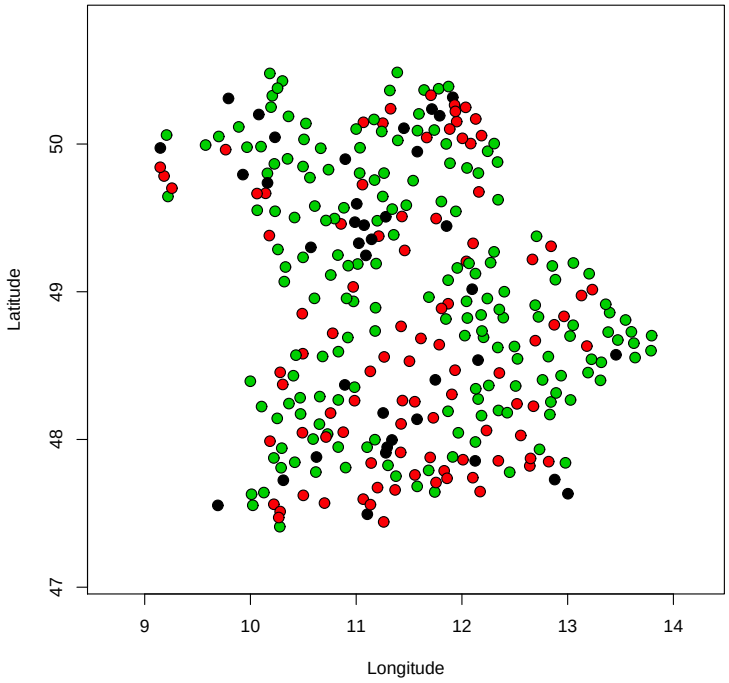
9 Figures

Figure 1: European Telephone Penetration Rates



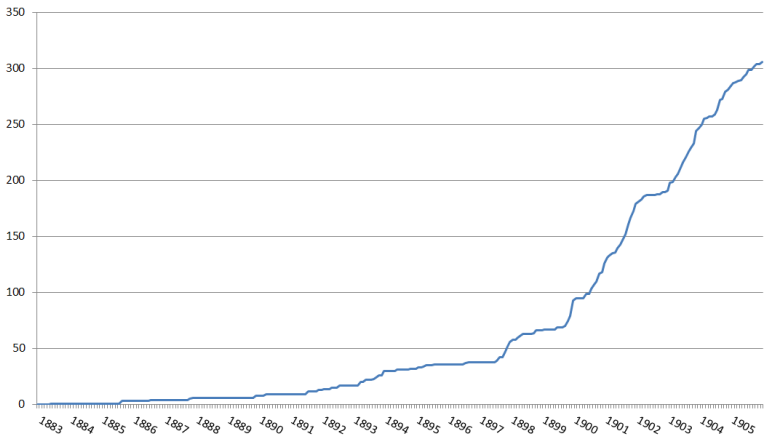
The graph plots the rate of per capita telephone penetration in a number of European states for the years 1896,1900 and 1905/06.

Figure 2: Location of Towns / Exchanges



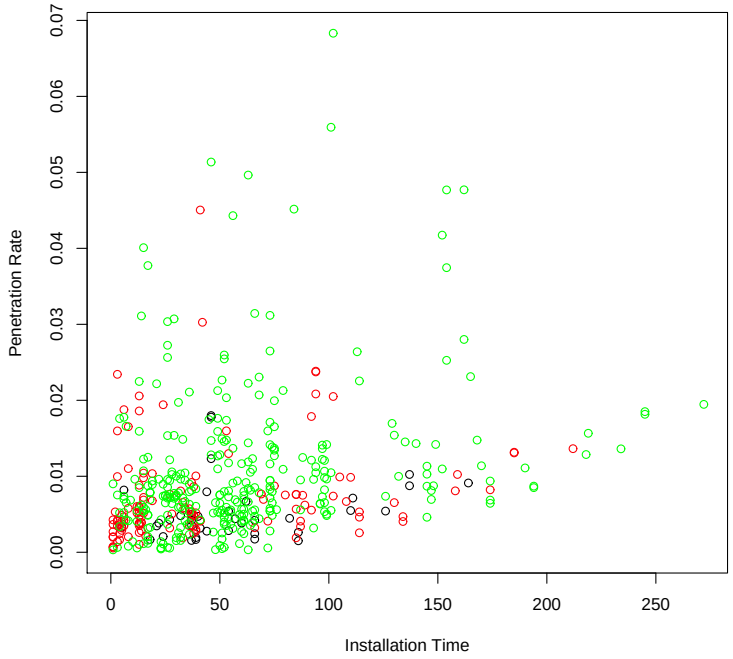
The graph plots the established local network exchanges. Black dots indicate towns with exchanges established before 1896, red dots were established before 1900 and green dots indicate those additionally installed before 1905.

Figure 3: Number of installed Exchanges



The graph plots the cumulative number of local exchange networks established in Bavarian Towns.

Figure 4: Bavarian Towns Penetration Rates



The graph plots the rate of per capita telephone penetration in Bavarian towns for the years 1896 (Black), 1900 (Red) and 1905 (Green).