Uniform Service, Uniform Productivity? Regional Efficiency of the Imperial German Postal, Telegraph, and Telephone Service.

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UNIFORM SERVICE, UNIFORM PRODUCTIVITY?
REGIONAL EFFICIENCY OF THE IMPERIAL GERMAN POSTAL, TELEGRAPH, AND TELEPHONE SERVICE

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Using the regional productivity of the Reichspost, the postal service of the German Empire, I investigate whether a public monopolist operates with uniform regional productivity. Using data envelopment analysis efficiency scores, we derive the relative productivity of the post, telegraph, and telephone sectors from 1891 to 1908. Results show a fairly stable system with substantial raw productivity differences between postal districts, and that the expansion of the service offset technological productivity increases for the mail service.

JEL categories: D24, L32, L87, L96, N74

Keywords: information technology, productivity, public monopoly

INTRODUCTION

Public services are usually expected to provide the same service in all regions they are tasked with covering. Despite the uniformity of rules, however, this does not imply that the level of service provision really is the same. Similarly, it does not imply that the efficiency and productivity with which the service is provided are the same in all regions. This study takes up the latter point in a case study to measure and understand the efficiency pattern between regional districts of a national, public monopolist. The historical situation investigated is the Reichspost, the Imperial postal service of the German Empire founded in 1871.

The time period under investigation, the two decades around the turn of the nineteenth century, were characterised by two main ideas relevant for the question of efficiency. First, the idea of universal access, the provision of an identical service to everyone everywhere, was a central tenant of a postal service continuing a rapid expansion. Second, the Reichspost was horizontally integrating different services with its scope ranging from the letters to parcels, financial services, passenger transport, and electric communication including the telegraph and the recently invented telephone. These two points are therefore the focus of the analysis. The central questions ask whether the idea of universal access led to a stable pattern of regional
efficiency and whether the various communication services, in particular mail, telegraph, and telephone, followed the same path during this period.

The nineteenth century saw a strong improvement in the systematic collection of statistical information, especially their quantity and quality. The Imperial Postal service is no exception, while its public nature made much of this information available outside of the institution. These statistics also demonstrate that the postal service’s organisational structure followed regional lines with a substantial number of operational characteristics broken down to the level of Oberpostdirektionen; regional postal districts lined up only partially with political boundaries. As these districts were only organisational units rather than autonomous policy-setting entities, this structure allows me to interpret regional differences as being due to operational differences rather than due to structural policy.

The question of the relative efficiency of distinct units engaging in the same productive activity – competing firms in the same market are the prime example – has long been of interest to a wide audience including managers, regulators, and academics. Indeed, the widespread business practice of Benchmarking is one prominent example. One of the origins of a systematic approach to measurement is the operations research literature that focuses on a formal, technical analysis of production process with multiple inputs and outputs. A central approach used in such applied work is to use mathematical or statistical techniques and the observed input/output combinations to determine the production possibility frontier (PPF). The relative efficiency of one decision-making unit (DMU) is then measured as some form of distance between the unit’s input/output set and the estimated PPF. The resulting score can be interpreted as a unit’s share of observed inputs necessary to produce the same observed output under optimal efficiency rather than the observed production process.

In this empirical analysis, I utilise a data envelopment analysis (DEA) approach to estimate the PPF and consequently calculate annual efficiency scores for 38 postal districts for the time period 1891 to 1908. The scores are calculated separately for the mail, telegraph, and telephone sectors of the Reichspost. In a second step, I then use a Malmquist index calculation to disentangle the effect of direct efficiency from technical changes for the comparison of efficiency scores between years.

The results indicate relatively stable average efficiency, although individual districts did catch-up or fall behind. The three services show similar patterns, although there are level differences. In terms of dynamic effects, the different services show similar means, although there are differences in the variance of changes with fatter tails for the newer technologies. One particularly noteworthy implication is that the frontier for the telephone shifts outwards, consistent with technological progress, while that for the mail is on average slightly contracting, indicating that the efficiency loss through the expansion of the services into smaller and smaller locations is outweighing technological advances during the period.

This frontier indicates the possible maximal output given a particular amount of inputs or alternatively the lowest amount of inputs needed to produce a given amount of output.
After a short discussion of the efficiency literature, I introduce the history of the German postal service as well as Germany more general. After outlining the data, I detail the precise formal analysis method applied. I then conduct the efficiency analysis for annual observations as well as the dynamic analysis over time. A final section concludes.

EFFICIENCY LITERATURE

The question of efficiency of firms has obviously spawned a large literature covering a wide range of empirical approaches. The field of Operations Research is a prime example for a thoroughly quantitative approach to analyse firm operations and performance.

Interest in the efficiency measurement of firm operations is, however, not only limited to decision makers within firms but also to outside parties, most notably industry regulators and policy makers. It is therefore not only focused on analysing private firms but covers public enterprises as well. Consequently, there is now a large literature measuring efficiency and performance of public utility companies, ranging from electricity and water to transport and much further.²

As the name Operations Research indicates, the focus of that literature is on the efficiency of operations within firms, that is, to use relatively fewer inputs to produce the same output. An important expansion of this approach is to include environmental factors in the analysis. These are circumstances, ranging from regulatory differences to market structures, political interference, or education structures that influence the efficiency of firm operations without being under the control of firms or are directly visible in the operations.

The efficiency measurement literature has incorporated these external factors in different ways. One main strand uses these exogenously given parameters precisely (e.g. directly controllable input variables) without formally distinguishing between them. An alternative approach uses a two-step process that includes endogenous variables only in the first step to calculate relative efficiency scores. The second step then takes these scores as dependent variables and estimates the relative importance of external factors using these as independent variables in a regression specification.³ This paper follows the second approach focusing on the first step of efficiency score determination with the second step analysis conducted in future research.

There are a few studies focusing on the efficiency of the postal service, though the extent of the literature is comparatively small. Although postal firms may use benchmarking and other methods internally, the nature of most postal firms as public monopolies has consequences for their treatment in the academic literature. In particular, the units of comparison are usually either complete national

² Coelli, A Primer and Coelli and Lawrence, Performance measurement.
³ Coelli et al., An Introduction; Bogetoft and Otto, Benchmarking.
While such studies follow the general methodology applied in this paper, there are a few other approaches focusing on different but related aspects. Examples are productivity changes of a single provider over time or the construction of a cost function. I am not aware of a study of this kind focusing on telegraph services; however, there is a substantial literature on the telephone and telecommunications more generally. Lam and Shiu (2008) provide an overview in their study on the Chinese telecommunications sector. Conceptually, that study comes also closest to this one as they use Chinese provinces as decision-making units. As the market is already open to private enterprises, however, they aggregate the regional inputs and outputs of active private firms to conduct their study.

HISTORICAL CONTEXT

German empire

Germany was one of the last of the major European nations to develop into a centralised nation state. While other states like France and especially Great Britain had created a unified state much earlier, Germany only developed a similar cohesion in 1871 with the foundation of the second German Empire.

The first empire, with its structure of several hundred sovereign territories and a supranational governance institution represented by the emperor, broke apart with Napoleon’s victory over German states at the turn of the nineteenth century. This led the Habsburg ruler to surrender the German emperor title and the demise of this institutional structure. Subsequent secularisation and mediatisation led to the consolidation of the sovereignties into a smaller number of states. After Napoleon’s loss, the Congress of Vienna redrew jurisdictional boundaries again and about 40 German states emerged, ranging from free cities like Frankfurt, to small and mid-sized states, and up to the large European powers of Austria and Prussia. Although there was a new institution in the German Federation, the Deutsche Bund, it only had very limited internal powers and functioned mostly as a military and internal security pact. There was some multilateral cooperation in economic issues, most notably the Zollverein customs union of 1834, but this consisted of purely voluntary treaties between sovereign nations and usually did not cover the whole of the German Federation.


This is practically discussed by Dodgson, *Economics of Postal Services*.

Mediatisation refers to the subsumption of smaller (or lesser) states into others.

Angelow, *Deutsche Bund*.

The tension between Austrian and Prussian claims to leadership in Germany escalated in the 1850s and 1860s until the full breakout of military conflict in 1866. Although most of the smaller German states allied themselves with Austria, Prussia achieved a swift military victory. As a result, it became the hegemonic power in Germany, pushed Austria out of Germany, and annexed many of the smaller states. Additionally, it created the Norddeutsche Bund, a formal union of German states north of the Main River under Prussian leadership. After the combined German troops beat the French in 1871, the political structure of Germany was once more reorganised, and the German empire was created as a federal structure of German states under the emperorship of the Prussian king.11

Although the new empire had centralised political institutions in Bundesrat, Reichstag, and Reichskanzler (respectively, the council of member state representatives, the parliament, and the chancellor), most practical executive issues remained under the control of the individual states’ political structures. The close connection between the imperial offices and their Prussian counterparts – for example, most chancellors were at the same time also prime ministers of Prussia – implied that the imperial executive had, in practice, more power than appeared on paper. There were also a number of immediate imperial offices, including the Reichspostamt, the postal service administration. This political structure persisted for over four decades and came to an end with Germany’s defeat in the First World War.12

The historical legacy of strong political fragmentation also affected other parts of German society, including its economic characteristics. The regions within Germany, partly following political borders but in many cases also crossing them, differed strongly in income, production, employment, and other structures. One particular aspect was the diffusion of the Industrial Revolution. Some regions, for example Saxony, had decisively entered the industrial revolution shortly after the Napoleonic wars; other regions lagged substantially and were strongly dominated by agriculture even decades later. The strong rise of the industrial Ruhr area, which became the centre of Germany’s heavy industry with large coal and steel operations, is one very visible sign of these different developments.13

**Reichspost**

In 1490, Maximilian I, who also ruled over the Netherlands, acquired control over Tyrol in Austria and subsequently tasked the Taxis family to provide a postal relay service between the two territories. This postal course is commonly seen as the origin of the modern European postal system and, with a southern extension into Italy,

11 Böhe, 1974, Deichtlandes Weg.
12 Hesse, Im Netz.; Pierenkemper and Tilly, The German Economy.
13 Pierenkemper and Tilly, The German Economy.
provided the central backbone of the system for the following two centuries. By 1530, the relay system had been opened to the public, and in 1597, Emperor Rudolf II went further and declared the post an imperial privilege, effectively granting the Taxis family a postal monopoly.  

As imperial power was severely limited at this time, some of the princes disputed the emperor’s right to assert this privilege and its related monopoly. This legal dispute was never fully resolved until the demise of the empire in 1806, so the privilege did not prevent the princes from establishing their own systems with a monopoly for their respective states. The most notable example was the Prussian system established permanently in 1649 in the wake of the peace of Westphalia. The existence of multiple systems persisted and left Germany following the reordering of the political landscape in 1815 with about a dozen different postal systems and the related difficulties of sending mail between them.

The increasing economic unification between the states also led to a push for a closer cooperation between the different systems to facilitate easier communication within the German territories. This came to a fruitful conclusion in 1850 when a number of states agreed to create the Postal and Telegraph union. In addition to coordinating telegraph transmissions, this agreement also created a unified German postal area, making it substantially simpler to send letters to recipients in another postal area.

The creation of the postal union coincided with some major structural changes to the systems. The introduction of prepaid mail through the use of stamps, started in Germany by Bavaria in 1849; the rise of the idea of universal access; and the shift towards distance-independent pricing structurally changed the existing services and provided the framework for the continued expansion of the postal reach and in particular for the spread from towns into the countryside.

Although the Taxis family had carried the operational, contingent financial risk of the mail services operated under imperial privilege, the postal service was never really conceptualised as a business venture. One formal example of this was the Zollverein treaty, which regulated which goods member states could assert as public monopolies; this did not list the postal service as such an area. Historically, the provision of mail services was therefore considered more of a public good – like security and defence, allowing the idea of universal access to rise and take hold.

Prussia’s victory in 1866 and the subsequent creation of the Norddeutsche Bund also led to the creation of a unified postal service. The Prussian service took over the existing structures in the other states of the North German federation and was then moved as a whole under the political jurisdiction of that new structure. This also

14 Behringer, Thurn und Taxis.
15 Behringer, Thurn und Taxis; Im Zeichen des Merkur.
16 Behringer, Thurn und Taxis.
17 von Stephan, Geschichte; Helbig, Bayerische Postgeschichte.
18 Behringer, Thurn und Taxis.
19 Parry, Consolidated Treaty Series.
meant the end of the Taxis postal service, which had survived as a private monopoly for a number of Hessian and Thuringian states as well as Wuerttemberg.20

A similar expansion happened with the foundation of the German Empire in 1871. Baden’s post service was folded into the Prussian system as was the formerly French service in Alsace-Lorraine. The resulting postal system became an official agency of the new Empire. There was, however, one substantial difference, namely, the roles of Bavaria and Wuerttemberg. While in 1867 Prussia had folded the postal services of all annexed states into the common system, this did not happen with the new imperial mail. The two southern states, Bavaria and Wuerttemberg, insisted on a number of special autonomy rights in exchange for their agreement to become part of the new empire. One of these was the retention of an independent postal service. This meant that inside the new empire, three distinct postal services operated. The size of the covered population, however, showed the relative disparity between them: the imperial mail serviced 36 million people while the Bavarian service covered just over 4 million and the Wuerttemberg service close to 2 million.21

The new imperial mail service was headquartered in Berlin, the political seat of the imperial government. A structural reform in 1876 merged the previously distinct post and telegraph administrations into the new Reichspost- und Telegraphen-Verwaltung. This new agency was headed by the Generalpostmeister, who reported to the chancellor of the empire.22 The position was filled by Heinrich von Stephan, an official who was instrumental in the creation of the Universal Postal Union in 1875. The service was organised in 40 postal districts called Oberpostdirektionen. These districts lined up roughly with internal political boundaries, and therefore the different predecessor postal systems, although the match was far from perfect. This structure existed until the demise of the Empire in the wake of Germany’s defeat in the First World War.23

The postal service not only took over the national telegraph services but also started to push the railroads, which had opened their telegraph systems for public transmissions, out of the business. Since the railroads’ telegraph systems were necessary for their operations, the state did not nationalise these systems but shifted traffic towards the expanding telegraph network of the postal service through non-compete regulations. Once the postal telegraph network served a connection, the railroad system was no longer allowed to transmit private telegrams between these locations.24

When direct electric communications became feasible with the invention of a practically useful telephone, the postal service also expanded its monopoly to this new technology. One of the major drivers behind this decision was the perception that the telephone was a complementary technology to the existing telegraph rather

21 Hesse, Im Netz, and Sautter, Geschichte der Deutschen Post, Teil 3.
22 After 1880 the agency was headed by a Staatssekretaer, who still reported directly to the chancellor.
23 Hesse, Im Netz, and Sautter, Geschichte der Deutschen Post, Teil 3.
24 Hesse, Im Netz, and Sautter, Geschichte der Deutschen Post, Teil 3.
than a substitute. This perception was likely based on the short-distance nature of the original telephone technology.\textsuperscript{25}

The formal integration of the telegraph and telephone into the organisation of the imperial postal service was the centrepiece of its horizontal integration. Besides these electric communication operations, it also offered a range of other services related to finance, newspapers, and travel. Like most postal services worldwide, it began to offer financial transaction services, in particular postal money orders. Ultimately, these evolved into full banking services. The Postbank ended up serving millions of clients, but this transformation only began substantially after the period investigated here.\textsuperscript{26} Another closely related service involved the distribution of news. The Reichspost operated a newspaper distribution system, which provided private consumers with the possibility to subscribe to a wide range of different news publications as well as running their practical distribution. Additionally, the postal services had for centuries used mail coaches to transmit items, and many German services had opened these coaches to private customers, offering transportation between towns all over Europe. The emergence of the railroads by the mid-nineteenth century, however, led to an end of the long-distance travel operations and diminished the extent of postal coach travel significantly.\textsuperscript{27}

DATA

Organising the service into distinct regional units implies that the quantitative data required for the analysis, that is, indicators for each postal district’s respective inputs and outputs, are readily available. The source of these postal data is the annual Statistischer Bericht, the statistical report, of the Reichspost.\textsuperscript{28} This report complements the Ergebnisbericht, a more qualitative description of the service’s operations (Deutsches Reich, Reichs-Post und Telegraphen-Verwaltung, 1876–1905), and provides a thorough statistical overview of the Reichspost’s service provision. Although most of the data are available from the mid-1880s, there was a structural reorganisation in 1890, which also led to changes to the reported statistics. Statistical reporting slowed substantially again in 1909. Consequently, the dataset utilised in this analysis contains annual observations from 1891 to 1908.

The data included in this set are all variables that either are under the direct control of the Postal service or represent factors authorised by the parliament but still administered by the service. As the focus of analysis is the determination of efficiency, productivity, and change before correcting for other influences, no additional district characteristics are included.\textsuperscript{29} Similarly, the included output data are all variables describing various aspects of the services provided by the postal service.

\textsuperscript{25} Ploeckl, Market Access.
\textsuperscript{26} Brüggemann, Das Milliardending.
\textsuperscript{27} Sautter, Die Geschichte der Deutschen Post, Teil 3 and Die Geschichte der Deutschen Post, Teil 2.
\textsuperscript{28} Deutsches Reich, Statistik der Deutschen Reichspostverwaltung.
\textsuperscript{29} The one exception is district population, which is used for weighting purposes of districts.
Input factors include the total number of employees, post offices, public mail boxes, offices offering telegram services, telegraph machines in these offices, telephone network exchanges, and the lengths of telegraph lines and within-exchange network telephone lines as well as wires. Output measures are the number of delivered letters, parcels, and newspapers as well as the number of travellers within postal coach services. Additionally, the number of telegrams collected and delivered is included as are the number of participants in the telephone system and the number of local, within-exchange, calls they made.

The utilised variables are quantity measures rather than ones indicating quality values. Possible examples for the latter would be the time to deliver a letter or telegram or the speed at which the phone service was able to establish the requested connection. Unfortunately, no data are available for these. Furthermore, services provided by multiple districts, for example, a letter between Hamburg and Berlin that would involve at least three districts, would be hard to assign clearly to a particular district. Conceptually, such measures are more directly customer-oriented, while this case study focuses predominantly on the internal service operations.

Table 1 describes the district populations as well as some of the input variables for the year 1891. This is complemented by information provided in the appendix of a recent working paper, which shows, besides area, also output variables like the number of letters and telegrams delivered per inhabitant. Map 1 shows a map of all 40 postal districts at the time, although the efficiency analysis will utilise the 38 districts listed in Table 1, leaving out Hamburg and Berlin due to systematic differences stemming from issues like the inclusion of central headquarters into the numbers and the accounting of international traffic.

**PRODUCTIVITY**

**Relative efficiency**

As indicated above, there are a number of different aspects of interest when measuring the productivity of public enterprises. Here, the focus is on efficiency in terms of the relative size of the output compared to respective input amounts; in this case, measured by calculating a Farrell efficiency measure for each region. This commonly used concept assigns each decision-making unit (i.e. a postal district in this case), an efficiency score which indicates the relative position of the unit’s input/output production combination versus the PPF. The latter describes the maximal amount of output that can possibly be produced given a specific amount of inputs and the best available technology. The efficiency score then compares this

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30 Ploeckl, *Uniform Service*.
31 The districts of Leipzig and Dresden cede some of their territory to a newly created district, Chemnitz, in 1897, which I do not include in the analysis at the moment.
32 Coelli, *A Primer*, and Coelli and Lawrence, *Performance measurement*.
33 Bogetoft and Otto, *Benchmarking*.
frontier with the observed production of a unit and calculates what share of the observed input is necessary to produce the same output given the optimal technology implied by the frontier. Practically, this score ranges between zero and one. A score of one indicates that the unit is fully efficient while 0.6, for example, implies that only 60 per cent of the inputs are necessary. This implies inputs could

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<td>Strassburg</td>
<td>1093</td>
<td>2757</td>
<td>854</td>
<td>519</td>
<td>6</td>
</tr>
<tr>
<td>TRI</td>
<td>Trier</td>
<td>748</td>
<td>1482</td>
<td>359</td>
<td>365</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Deutsches Reich (1891–1908).
be reduced by 40 per cent, and the resulting output would still be the same with the use of the optimal production technology.34

The main step necessary for this calculation is the determination of the PPF. As the optimal technology underlying the frontier is usually unknown, an empirical approximation using the observed production combinations is utilised.35 There are a number of different approaches available to derive this frontier. The choice of an appropriate method therefore needs to take into account which underlying assumptions about the production technology the different approaches make as well as any potential trade-offs with data requirements, measurement, and precision.

Most methods utilised in empirical studies are variations of two main underlying conceptual approaches: DEA and stochastic frontier analysis (SFA). These two differ in two central dimensions: DEA is non-parametric while SFA requires an underlying parametric form; and DEA is deterministic while SFA takes observations as outcomes of a stochastic process. Practically, SFA uses a regression approach that requires a single outcome measure and the specification of the production function, but it can accommodate extreme values and outliers. Data envelopment analysis takes all observed production

34 Alternatively, to the described ‘input-oriented’ approach, there is also an ‘output-oriented’ measure, which focuses on the amount of additional output the application of optimal technology to a given input combination would have achieved.

35 Alternatively, an ‘engineering’ approach could be adopted, which utilises information about the actual production process to make a technical judgement about the optimal efficiency achievable; see Bogetoft and Otto, Benchmarking.
combinations as possible and spans the frontier as a multidimensional hull around these observations.36

Given the characteristics of the dataset, the DEA approach is more appropriate. This is mainly because of the nature of the output data and the number of observations. The SFA requirement of a single output measure implies that relative weights need to be imposed to combine distinct services.37 While prices are suitable as weights, there are a number of outputs, for example, the number of letters delivered, that have no clear price, making it rather problematic to assign correct weights.

Data envelopment analysis allows the incorporation of multiple outputs without specifying their relative importance. Similarly, DEA has a substantially lower data requirement as its validity is less dependent on having a sufficient sample size than the SFA regression approach. This allows the calculation of efficiency scores on an annual basis with just 38 district observations and multiple input and output factors.

As mentioned, the DEA methodology uses the observed production combinations of the respective units to span the frontier as a multidimensional hull around them. The exact shape of that frontier depends on a number of choices about particular characteristics. Important ones are convexity, which implies that any linear combination of two production combinations is also feasible, and free disposability, which implies that input factors can be disposed without consequences. The particular operational structure of the postal service fits fairly well with these two characteristics, and so the following will presume that they hold.

A third important choice is the selection of a particular return to scale characteristics. There are four possibilities: constant returns to scale (CRS); increasing (IRS); decreasing (DRS); and variable returns to scale (VRS), with the latter being a particular combination of the others. The main impact of the choice refers to how the production process scales, that is, CRS imply that size is essentially irrelevant and the production process scales up and down in a constant way. IRS implies that a larger size can only have advantages while DRS implies that a larger size can only have disadvantages. VRS combines IRS at the ‘lower end’, with the implication that there is a minimum scale below which production is not feasible, with a switch to DRS at the ‘upper end’, including a maximum size above which no further output increase will be achieved. As certain aspects of the different components of the various postal services fit with the different assumptions, most of the following analysis is done twice, once with the CRS assumption and once with VRS.

SERVICES

As described above, the Imperial postal service had expanded the range of its services beyond the core mail service covered by its monopoly. Besides various forms

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36 Coelli et al., An Introduction, and Bogetoft and Otto, Benchmarking.
37 District revenue numbers are only available for all services together but not on an individual service level.
of mail, including parcels, and electric communications like the telegraph and telephone, it also offered financial as well as travel services. The latter were mainly post coach services that over time shrank substantially through the expansion of the railroad network and later due to the emergence of automotive transportation. This multitude of services complicates determining the relative efficiency of the postal service as whole, but offers the opportunity to focus on distinct parts. Here, the focus is on comparing the productivity between the ‘old’ mail service and the two ‘new’ communication methods, the telegraph and telephone. Practically, the analysis is therefore conducted three times, once using the inputs and outputs of the traditional mail service part, once using telegraph related factors, and once using telephone data.

The main assumption necessary is the selection of the corresponding input and output variables. For the mail service, I include the total number of employees, post offices, and mailboxes as inputs and the number of delivered letters, parcels, and newspapers through the postal subscription system, and the number of travellers in the postal system as outputs. For the telegraph, I include the number of telegraph offices and telegraph machines and the length of telegraph lines as inputs while the respective numbers of telegrams collected and delivered are used as outputs. For the telephone, I use the number of network exchanges, the length of the lines as well as the length of the wires within those local networks as inputs. Outputs are the number of participants as well as the number of connections made within a district’s local networks.

This allocation contains a number of trade-offs. The first is the inclusion of all employees within the mail service and their exclusion for the other two services. As the official statistics do not distinguish employment between the different services, this choice is based on the vast majority of employees working in the mail services, which are quite labour intensive, while the numbers in the much more capital intensive telegraph and telephone services are comparatively small. The next choice is the exclusion of financial service variables, especially as an output. The main reason is that the relative amount of services provided pales in comparison to the regular mail services, and there are only a few dedicated employees who are solely or even just predominantly working in this area. Additionally, the analysis focuses on the efficiency of the service rather than the financial results that might be more influenced by these activities. The next choice is the inclusion of all Fernsprechverbindungsanlagen-Linien, that is, phone lines between exchanges, within the telegraph sector. The reason is that for most of the years available, the statistics category counts both telegraph and telephone lines within the same category. With the rise of the telephone, the share of lines for that service rises, but the bulk is still

38 The number of variables available per year is close or even larger than the number of districts, which makes calculations utilising all of them essentially impossible.

39 The table in the online appendix shows the stark difference between the number of letters and telegrams delivered, additionally in Berlin five out of six employees are in the mail service, see Deutsches Reich, Bericht ueber die Ergebnisse 1891. The number is certainly higher in more rural districts.
dedicated for the transmission of telegrams. This combination of overland telegraph and telephone lines is also the reason the phone service statistics are focused on the provision of local services; all the respective variables only cover local lines, wires, and calls. Since the absence of information about the length of the overland telephone lines implies that one important, if not the most important, input is missing for the total service provision, I focus on local phone service exclusively and exclude all between-exchange phone services.

SERVICE EFFICIENCY

The efficiency scores for districts are calculated annually for each of the three services with the VRS and the CRS assumptions. The online appendix shows the results for each specification graphically as a grid with the colour of the grid cell indicating the score of the particular district (rows) in a particular year (columns). Additionally, the districts are reordered to form clusters of units with similar score patterns, enabling an easier visual comparison.

To provide a more summative and comparable view, I calculate the population-weighted average efficiency scores for each year for each scenario and depict these in Figures 1–3.

The plots for the mail service show a slight upward trend over the whole period. There is a slight peak around 1900/1901, especially for the CRS-based average, but the fluctuations are fairly minor. There is somewhat of a level difference between the VRS and CRS-based score averages, but the development over time appears to be quite parallel. The plots for the telegraph service differ from this picture. The graph shows a slight downward trend, which is more pronounced under the CRS than under the VRS assumption. Additionally, the gap between CRS and VRS is larger than for the mail service and appears to widen over time. The results for the phone service...
service show after an initial period of persistence a slight downward trend followed by a stronger upward movement starting after a trough in 1904. The results for VRS and CRS are closer than for the other measures and move in parallel over the time period.

Similarly, Figures 4 and 5 show the standard deviations of the annual efficiency scores, first for the three services under the VRS assumption (Fig. 4) and then for the three services calculated with the assumption of CRS (Fig. 5).

There are some similarities in the results under both assumptions; the variance for the mail service stays fairly constant and is substantially below that of the telegraph service. Similarly, the phone service in both cases has a downward trend, especially
in the last few years, resulting in a standard deviation below that of the other two. In terms of differences, the telegraph service shows a stronger downward trend under the CRS assumption. Similarly, the level of the variance at the start of the period is higher for the telegraph service than the telephone service under CRS but not under VRS.

The results indicate that the Imperial postal service had consolidated its operations by 1890 such that the aggregate pattern of regional efficiency, especially in the mail as well as telegraph service, remained consistent between districts. This does not preclude differential developments occurred in other district characteristics – for example, industrialisation had an impact – however, these developments were offset, either through a relatively fast reaction by the postal service or through an offsetting effect of other developments. Later, I discuss whether this distributional stability is mirrored in the regional pattern of the efficiency scores.
The results for the phone service indicate that this new technology followed a somewhat different pattern. The high average scores indicate that the technical uniformity of the implementation led to relatively comparable efficiency levels with the decreasing variance indicating that lagging districts were catching up substantially over this time period of rapid expansion of the service.

**Dynamic efficiency**

The scores calculated in the previous section are all relative to the frontier of their particular years. This has implications for the comparison of a particular district’s scores between two years. If, for example, the score increases from 0.75 to 0.78, it implies that the district became more efficient relative to the respective frontier but not that the district actually became more efficient. It is possible that the technological frontier shifts in such a way that the efficiency decreases yet the score increases (or efficiency increases yet the score decreases).

To incorporate technological development into this calculation, I use a Malmquist Index using DEA efficiency scores.\(^{40}\) Formally, for two time periods \(s\) and \(t\), the index is

\[
M(s, t) = \sqrt[\cdot]{\frac{E(t, s) \cdot E(s, s)}{E(t, t) \cdot E(s, t)}}
\]

where \(E(s,t)\) is the district’s efficiency score for the input/output combination in period \(s\) measured against the technological frontier in period \(t\). The index is the geometric average of the change in efficiency from \(s\) to \(t\) keeping technology fixed in period \(s\) and the change in efficiency using technology of period \(t\) for both periods.

The index can be rewritten as

\[
M(s, t) = \sqrt[\cdot]{\frac{E(t, s) \cdot E(s, s)}{E(t, t) \cdot E(s, t)}} = TC(s, t) \cdot EC(s, t)
\]

where

\[
TC(s, t) = \text{Technical change} = \sqrt[\cdot]{\frac{E(t, s)E(s, s)}{E(t, t)E(s, s)}}
\]

\[
EC(s, t) = \text{Efficiency change} = \sqrt[\cdot]{\frac{E(t, t)}{E(s, s)}}
\]

This implies that the relative change in efficiency can be decomposed into a technical change component, which is the effect of the change in technology from

---

period $s$ to $t$, and an efficiency change component, which is the change in the position relative to the frontier.

There are a number of practical and conceptual reasons that this decomposition is only appropriate for DEA efficiency scores calculated with the CRS assumption.\footnote{Coelli et al., An Introduction.} The following calculations are therefore all conducted with this particular assumption.

**Service productivity changes**

I calculate these Malmquist efficiency indices for productivity changes, as well as for technical and efficiency changes, annually for all three services.

As Figure 6 shows, the postal (mail) service has clearly the lowest dispersion, followed by the telegraph service, while the phone service has the widest spread in terms of the size of productivity changes.

Figures 3 and 4 in the online appendix show the average annual change for the three services decomposed into efficiency and technological change. Especially for the case of the telegraph service, it appears that technological change is more volatile than efficiency changes. Given the larger discrepancy between the VRS and CRS assumptions for the telegraph, however, this result might be influenced by the stronger effect of the CRS assumption used in the calculation.

Comparing the volatility of efficiency and technological changes with that of the above shown productivity changes shows that the latter is between these two components, which imply a negative correlation between the two. This is confirmed by the panels in Figure 7, which clearly show this negative relationship in scatter plots between the two corresponding values.

This relationship implies that in years during which lagging districts catch-up, the frontier also moves ahead. Practically, this indicates that technological progress, as indicated by an outward shift of the production possibility frontier, is stronger in lagging districts, leading to an induced catch-up effect. The derived technical change values also allow conclusions to be drawn about the general direction of the PPF frontier movement. As Figure 6 demonstrates in combination with Figures 1 and 2 in the online appendix, the median values for the mail and telegraph are larger than one, while that for the phone service is clearly below one. In practical terms, a value below one implies the frontier is moving outward and away from the given production combination, while a value larger than one implies the opposite; the frontier moves inward and closer. This indicates that the PPF for the phone sector was shifting outward during the period, indicating general technical progress within the sector. The values for the mail and telegraph indicate either a decrease in technical progress or, as is more likely, a slight inward shift of the PPF due to the decreasing returns of expanding the services into more and more locations, outweighing any direct technical progress.\footnote{This presumes that the services were located initially in the more profitable locations that allow more efficient operations. See Ploeckl, Market Access, which makes this point for the Bavarian telephone expansion during a similar time period.}
Correlation patterns

The average efficiency of the three services shows a certain similarity, although differences in level and short-term trends are visible between them. Figure 8 shows the pairwise correlation between the district efficiency values for the three services over time.

In contrast to the relative stability of the average efficiency values, these correlations show substantial changes over time. The start of the period is characterised by a very high correlation between mail and telegraph services, substantially lower correlation between telegraph and telephone services, and a very low correlation between mail and telephone. There are two main developments
over time: first, an extremely strong increase in the correlation between the mail and the telephone between 1895 and 1903, which is followed by a general decrease in all three correlations in the last 5 years of the time period.

Similar to the correlation between the services, the average efficiency trends can mask underlying geographical patterns within each service. Although the focus of this paper is descriptive rather than explanatory, an examination of these patterns using 1891 and 1903 as reference points will follow.43 Map 1 and the five maps in the online appendix show graphically the regional efficiency measures using the VRS assumption at the start of the period in 1891 and the above mentioned high point in inter-service correlation in 1903.

The regional distribution of efficiency scores for the mail service shows a slightly uneven, but overall fairly consistent regional pattern for 1891. By 1903, the pattern becomes even more distinctive in smoothing out an east–west gradient of scores, indicating a decrease in efficiency the further east a district is located. The pattern for the telegraph in 1891 exhibits a similar gradient, though a more jarring structure in the centre of the country. The pattern becomes more polarised by 1903 with a few districts in the west showing high scores, while the remaining districts have more or less evenly distributed scores. The phone scores of 1891 show a fairly even distribution of high scores across all areas with a few low outliers. By 1903, the east–west gradient is very visible, consistent with the strong increase in correlation between the mail and phone scores. This formation of a regional pattern, however, is overshadowed by the catch-up effect shown previously in the average and variance of the phone efficiency scores.

43 It cannot be distinguished here whether the regional patterns are due to exogenous differences in underlying district characteristics or endogenous service operations.
Conclusion

Public monopolies, in contrast to their private counterparts, are usually expected to provide the same service in the different regions of their respective monopoly territories. The postal service is no exception. In the nineteenth century, it was a prominent symbol of this ideal. The idea of universal access shaped its development in many industrialising countries, providing a template for the rise of nationwide public services. Nominally equal access, however, does not imply that the service functions equally efficiently in all regions. The determination of the efficiency of a public enterprise is one application of a vast literature on efficiency and productivity measurement. This paper utilises the DEA methodology to identify the regional efficiency differences in the provision of communication services through a public monopoly.

The particular situation of the German postal service also allows comparison of the relative efficiencies in different communications sectors, in particular, the mail, telegraph, and telephone services. These methods of information transmission differed substantially in their age, existing diffusion and adoption, capital and labour intensity, and technological progress during this period.

The results indicate that the underlying efficiency differences were fairly stable, although substantial, over time. Regional patterns shifted slightly over time, although the variance of efficiency scores correlated with the age of technology. Dynamic effects follow a similar pattern, with the variances of productivity, technical, and efficiency changes aligning with the age of the technology.

One particular interesting result is the relative strength of technological progress and the effects of universal access expansion. The production possibility frontier for the telephone shifted outwards while that for the mail service had a slight inward orientation. This implies that for the new technology of the phone, technical progress was dominating efficiency development, while for the established technology of the mail service, the negative impact of continued expansion in the name of universal access outweighed any potential technological progress. This last point is an important reminder that public service enterprises do not necessarily have efficiency as their central goal, especially if the state controls a whole sector through a public monopoly. Measuring technological progress in such sectors therefore needs to take into account that the sector’s measured efficiency might be below the actual technological capability of the service.

These results open up a basis for future research to determine how much of these efficiency differentials were really efficiency gaps and how much can be explained by external factors. The time period considered here saw a range of economic and societal changes, including further industrialisation and urbanisation, so the stability of the regional efficiency pattern of postal service provision indicates that adjustments by the Reichspost were probably more related to long-term trends than to short-term change.
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