Vertical Differentiation in Two-Sided Markets
An Analysis along German Personal Transport Intermediation

Von der Fakultät Wirtschafts- und Sozialwissenschaften der Universität Stuttgart
zur Erlangung der Würde eines Doktors der Wirtschafts- und
Sozialwissenschaften (Dr. rer. pol.) genehmigte Abhandlung.

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Tag der mündlichen Prüfung	7. Dezember 2022

Institut für Volkswirtschaftslehre und Recht der Universität Stuttgart

2022

In greatful memory of Anne and Rolf

Acknowledgements

This dissertation was written at the Institute for Economics and Law of the University Stuttgart. At this point I like to address my gratitude to everybody inspiring, motivating and helping me to write the present work.

Namely, I thank my supervisor Prof. Dr. Bernd Woeckener for his ideas, comments and guidance. In addition I thank Prof. Dr. Frank C. Englmann for asking constructive questions and both for giving advice during the PhD seminar.

I thank my colleagues Magdalena Auer, Dr. Stefan Freund, Volker Hilla, Dr. Daniel Missal, Thomas Hansmann, Virginia Springer, Dr. Till Berkefeld, Frank Calisse, Benjamin Bätz, Yonas Ogbamicael, Dr. Susanne Becker and Dr. Marion Aschmann for their comments on my research, our diverting lunch brakes and pleasant working atmosphere. In the same manner I want to express my thanks to our secretaries Gisela Maurer-Widmann, Carmen Ratzinger, Sandra Brinkschulte and Claudia Feucht for always coordinating exams and managing my requests.

Furthermore, great thanks goes to Sebastian Schöneck. His pertinent cues on European Policy and his sincere companionship are highly valued. And I thank Alyona Khaslavskaya for her motivation and for sharing her perspective. Beyond, my gratitude goes to Dr. Johannes Bleher for his constant interest in my work. I appreciate his helpful comments and discussions in particular while proofreading.

At last, I express my dearest gratitude to all of my friends, my family, the brotherhood, my in-laws, my marvellous parents and finally to Nicole for her patience, support and love.

December 2022, Schorndorf

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Abbreviations

AG	Aktiengesellschaft — German for public company
API	Application Programming Interface
ARGE	Arbeitsgemeinschaft
AVV	Aachener Verkehrsverbund
AVV	Augsburger Verkehrsverbund
BayÖPNVG	Gesetz über den öffentlichen Personennahverkehr in Bayern
BKG	Bundesamt für Kartographie und Geodäsie
BLT	Baselland Transport
bodo	Bodensee-Oberschwaben Verkehrsverbund
BMWi	Bundesministerium für Wirtschaft und Energie
BVG	Berliner Verkehrsbetriebe
BVWP	Federal Transport Investment Plan/Bundesverkehrswegeplan
BW ÖPNVG	Gesetz über den öffentlichen Personennahverkehr in Bayern
CEF	Connecting Europe Facility
DB	Deutsche Bahn
DING	Donau-Iller-Nahverkehrsverbund
ENeuOG	Eisenbahnneuordnungsgesetz
EU	European Union
e.V.	eingetragener Verein — German for registered club

FOC	First Order Condition
GmbH	Gesellschaft mit beschränkter Haftung — German for private limited company
GPS	Global Positioning System
GUI	Graphical User Interface
GVH	Großraum-Verkehr Hannover
GWB	Gesetz gegen Wettbewerbsbeschränkungen
HADAG	Hafendampfschiffahrts-Actien-Gesellschaft
hib	Heute im Bundestag
HHA	Hamburger Hochbahn AG
HHI	Herfindahl-Hirschman Index
HNV	Heilbronner-Hohenloher-Haller Nahverkehr
HÖPNVG	Gesetz über den öffentlichen Personennahverkehr in Hessen
htv	Heidenheimer Tarifverbund
HVV	Hamburger Verkehrsverbund
IGEB	Interessengemeinschaft Eisenbahn, Nahverkehr und Fahrgastbelange Berlin e.V.
INVG	Ingolstädter Verkehrsgesellschaft
IP	Internet protocol
ITS	Intelligent Transport Systems
KVV	Karlsruher Verkehrsverbund
LAVV	Landshuter Verkehrsverbund
LVG	Landsberger Verkehrsgemeinschaft
LVS	Landesweite Verkehrsservicegesellschaft
MaaS	Mobility-as-a-Service

marego Magdeburger Regionalverkehrsverbund

mbH cf. GmbH

MDV Mitteldeutsche Verkehrsverbund

MiD Mobilität in Deutschland

mona Mobilitätsgesellschaft für den Nahverkehr im Allgäu

MVG Münchner Verkehrsgesellschaft

MVV Münchner Verkehrs- und Tarifverbund

NAH.SH Nahverkehrsverbund Schleswig-Holstein

naldo Verkehrsverbund Neckar-Alb-Bodensee

NASA Nahverkehrsservice Sachsen-Anhalt

NRW North Rhine-Westphalia

NVR Zweckverband Nahverkehr Rheinland

NVV Nordhessischer Verkehrsverbund

NVS Nahverkehr Schwerin GmbH

NWL Zweckverband Nahverkehr Westfalen-Lippe

NWN Nahverkehrsgemeinschaft Weiden-Neustadt an der Waldnaab

OECD Organisation for Economic Co-operation and Development

OEM Original Equipment Manufacturer

ÖPNV Öffentlicher Personennahverkehr/public transport

ÖPNVG Gesetz über den öffentlichen Personennahverkehr im Freistaat Sachsen

ÖPNVG NRW Gesetz über den öffentlichen Personennahverkehr in Nordrhein-Westfalen

OTC Over-the-Counter

PBefG Personenbeförderungsgesetz

RegG	Regionalisierungsgesetz
RMV	Rhein-Main-Verkehrsverbund
RNN	Rhein-Nahe Verkehrsverbund
rnv	Rhein-Neckar-Verkehr
RoVG	Roseheimer Verkehrsgesellschaft
RVF	Regio-Verkehrsverbund Freiburg
RVL	Regio Verkehrsverbund Lörrach
RVV	Regensburger Verkehrsverbund
SaarVV	Saarländische Verkehrsverbund
SSB	Stuttgarter Straßenbahnen
SERVQUAL	Service Quality Measure
SH-Tarif	Schleswig-Holstein-Tarif
SMS	Short Message Service
SSNIP	Small but Significant and Non-transitory Increase in Price
swa	Stadtwerke Augsburg
TaaS	Transport as a Service
TEN-T	Trans-European Transport Network
TGO	Tarifverbund Ortenau
TON	Tarif Oberpfalz Nord
TUTicket	Verkehrsverbund Landkreis Tuttlingen
UPP	Upward Pricing Pressure
VAB	Verkehrs- und Tarifgemeinschaft am Bayerischen Untermain
VAG	Freibuger Verkehrs AG
VAS	Verkehrsgemeinschaft Amberg-Sulzbach
VBB	Verkehrsverbund Berlin-Brandenburg

VBN	Verkehrsverbund Bremen/Niedersachsen
VDR	Verkehrsgemeinschaft Donau-Ries
VDV	Verband Deutscher Verkehrsunternehmen
VEJ	Verkehrsverbund Ems-Jade
VG GAP	Verkehrsgemeinschaft Garmisch-Partenkirchen
VGC	Verkehrsgesellschaft Bäderkreis Calw
VGC	Verkehrsgemeinschaft Cloppenburg
VGB	Verkehrsgemeinschaft Grafschaft Bentheim
VGC	Verkehrsgesellschaft Bäderkreis Calw
VGF	Verkehrsgemeinschaft Fichtelgebirge
vgf	Verkehrs-Gemeinschaft Landkreis Freudenstadt
VGI	Verkehrsgemeinschaft Region Ingolstadt
VGN	Verkehrsgemeinschaft Niederrhein
VGN	Verkehrsverbund Großraum Nürnberg
VGV	Verkehrsgemeinschaft Landkreis Vechta
VHB	Verkehrsverbund Hegau-Bodensee
VHP	Verkehrsgesellschaft Hameln-Pyrmont
VLC	Verkehrsgemeinschaft Landkreis Cham
VLD	Verkehrsgemeinschaft Landkreis Deggendorf
VLK	Verkehrsgemeinschaft Landkreis Kehlheim
VLN	Verkehrsgesellschaft Landkreis Nienburg
VLMÜ	Verkehrsgemeinschaft Landkreis Mühldorf
VLP	Verkehrsgesellschaft Landkreis Passau
VLS	Verkehrsgemeinschaft Landkreis Schaumburg
VMS	Verkehrsverbund Mittelsachsen

VMT	Verkehrsverbund Mittelthüringen
VNN	Verkehrsgemeinschaft Nordost-Niedersachen
VOS	Verkehrsgemeinschaft Osnabrück
VPE	Verkehrsverbund Pforzheim-Enzkreis
VRB	Verkehrsverbund Region Braunschweig
VRG	Verkehrsgemeinschaft Röhn-Grabfeld
VRGI	Verkehrsgemeinschaft Rottal-Inn
VRN	Verkehrsverbund Rhein-Neckar
VRM	Verkehrsverbund Rhein-Mosel
VRR	Verkehrsverbund Rhein-Ruhr
VRS	Verkehrsverbund Rhein-Sieg
VRT	Verkehrsverbund Region Trier
VSB	Verkehrsverbund Schwarzwald-Baar
VSL	Verkehrsgemeinschaft Straubinger-Land
VSN	Verkehrsverbund Süd-Niedersachen
VSW	Verkehrsgemeinschaft Schweinfurt
VVG	Verkehrsgesellschaft Vorpommern-Greifswald mbH
VVM	Verkehrsunternehmens-Verbund Mainfranken
VVM	Verkehrsverbund Mittelschwaben
VVO	Verkehrsverbund Oberelbe
VVR	Verkehrsgesellschaft Vorpommern-Rügen mbH
VVR	Verkehrsverbund Rottweil
VVS	Verkehrsverbund Stuttgart
VVV	Verkehrsverbund Vogtland
VVW	Verkehrsverbund-Warnow

WAP	Wireless Application Protocol
WTV	Waldshuter Tarifverbund
WVV	Würzburger Versorgungs- und Verkehrs-Gesellschaft mit beschränkter Haftung — German for private limited company (GmbH)
ZVON	Zweckverband Verkehrsverbund Oberlausitz-Niederschlesien
ZVNL	Zweckverband für den Nahverkehrsraum Leipzig

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Latin characters

A	Set of users
B	Set of users
b	Bid function
c	(Development) costs
CM	Covered market
D	Demand
e	Scaling parameter to account for differences in market size on different market sides
F	Distribution of passengers in a search market according to their willingness to pay
G	Distribution of transport firms in a search market according to their reservation prices
h	Constraint function
I	Intermediary
JCM	Just-covered market
N	Number of users
p	Price
Q	Trading volume
r	Surplus

S	Supply
s	Quality measure
SM	Search market
u	Utility
U	Uniform distribution function
UM	Uncovered market
V	Benefit value
W	Willingness to pay

Greek characters

α	Transport firm's expected additional profit
ε	Price elasticity
η	Scaling parameter for costs
θ	Passengers' valuation of time savings
κ_α	Density of transport firms
κ_θ	Density of passengers
λ	Probability of a match in a search market
μ	Multipliers for inequality constraints
Π	Platform profit
τ	Probability of being rationed by an intermediary

Subscripts and superscripts

a	Ask
b	Bid
i, j, k	Indices for individuals of a group
l	Lower bound
ind	Indifference
p	Passengers
sh	Single-homing
t	Transport firms
u	Upper bound

Abstract

This dissertation discusses two-sided markets from a vertical differentiation point of view. To illustrate the problem, urban personal transport serves as a practical example. In a first step, the rough characteristics and development of the German personal transport market are assessed. The focus lies on German transport intermediation in form of transport unions and associations. Along these, digital services for travellers and the role of intermediaries are reviewed. While discussing the evolution of transport intermediation, the legal foundation for subsidised transport and its organisation are explicated. From a service-centered view on mobility, a shift of power towards authorities supervising transport associations is recognised within this discussion. In the extreme case, where transport firms are private ventures, an intermediary provides Mobility-as-a-Service (MaaS).

The research shows that technological progress promotes efficiency of the transport system and its organisation. In the German market, digital information and ticketing applications have been established in the past 20 years and represent nowadays the market standard in metropolitan areas. Since public transport falls within the remit of federal states, there are some states where public transport is governed by the central administrative body while in some other states public transport beyond rail services is delegated to counties or municipalities. Especially in Bavaria and Lower Saxony as well as in Mecklenburg-Vorpommern, this has lead to a fragmented public transport. The analysis shows that in these fragmented areas the rural regions are less likely to offer modern distribution channels or information tools. It also indicates that the mobility market is less developed in these rural environments offering tendered bus and rail line services, only. For the population this means that for example no sharing services are offered.

New forms of transport supplied by predominantly private ventures can be found in metropolitan areas offering for example car-sharing, rental bikes and pooled taxi services. While at market entry, these transport firms offer their own interfaces to communicate with customers and to conduct their sales, open intermediaries facilitate interconnection between multiple transport offerings as the services become established. This is similar to the original idea of transport associations, but includes non-tendered services that are available on demand, as well. The benefits for travellers lie in extended information on transport supply and a higher degree of market transparency. This results in possible travel time reductions as tailored solutions can be offered. Beyond this, an intermediary can help travellers to find the means of travel that matches their budget or, accordingly, their willingness to pay.

For transport firms, the intermediary represents a cost-efficient sales channel that, depending on the user base, becomes more attractive. I.e. the more passengers are actively affiliated to the intermediary, the higher the likelihood that they will book a ride generating revenue for the transport firms. This dependence on the number of users on the other market side represents a (cross) network externality. An intermediary harnesses this effect and takes it into account when pricing its services to both passengers and transport firms.

Passengers and firms have the possibility to abstain from a mobility platform by choosing a mode that is not supported (by the platform). Alternatively, the two parties can interact directly without relying on an intermediary's services. Therefore, the role of intermediaries is discussed along a brief review of their contribution to reduce transaction costs, perform matching and to offer immediacy. With regard to transaction cost and endogeneity of demand, the remarks are backed by a simple market model. In such a model, three possibilities emerge: a) a single intermediary offering guaranteed transactions, b) a search market, where agents are matched randomly leading to bargaining that can fail and, finally, c) some agents refraining from active participation at all.

Since this approach is confined to a single intermediary, non-price competition with regard to differentiation and network effects are discussed. The main focus

of the review is put on vertical differentiation, which is tantamount to non-price effects with regards to a quality characteristic. This approach is versatile concerning market structure, mapping both monopoly and oligopoly as well as exogenous and endogenous demand. To corroborate these results, a general model on quality competition is established. In addition, the general aspects of network effects are presented to motivate the interdependence of market participants and to provide a basis for the discussion of two-sided markets that follows.

This discussion represents a literature review along the topics of market entry into platform markets, on how to deal with asymmetric market structures and the consequences on pricing. In addition, antitrust issues are briefly discussed along the problem of defining the relevant market and its limits. The review is concluded by a dedicated model for vertical differentiation in platform market. As this model entails strong assumptions with regard to the associated user groups, a dedicated model on personal transport intermediation is designed in the following chapter.

The model for a personal transport platform is built along the vertical differentiation paradigm that passengers benefit from a matching technology platforms invest in. Transport firms on the other hand benefit from an easy access to passengers and value the number of passengers affiliated to an intermediary. To comply with the observations of the German transport market and its intermediaries, where both regions with a single platform or with multiple platforms exist, both the monopoly and a competition case are designed.

For a monopoly platform, four different market configurations have been established. These include the combinations where passengers and transport firms fully or partly rely on the services of the monopolist. The configurations depend largely on the characteristics in terms of both heterogeneity and size of demand of the two user groups. In a final step, the monopolist maximises his profits along the choice of quality offered to passengers, i.e. how much to invest into the matching technology. At the same time, he takes the characteristics of the two user groups into his account.

In the duopoly case, the number of possible market outcomes is even higher than in a monopoly market. In the transport market, three outcomes are discussed

including a) a covered market, b) the knife edge case where all firms participate due to a particular pricing rationale of the low quality platform and c) an uncovered market. For passengers, the distinction is limited to two conditions: either all travellers use the services of one of the platforms or some passengers abstain from platform participation. In total this yields six market configurations.

The game played by the intermediaries consist of three stages, where in the first stage, quality (to passengers) is determined, followed by the two price games on either market side. To solve the game recursively, transport prices are determined in the first subgame. This subgame offers pure equilibria for all possible market outcomes. For the remaining subgames of passenger price and quality determination, a pure equilibrium can only be attained in the case where both markets are covered. The remaining market configurations allow only for mixed strategy equilibria.

Overall, the investigation shows that a duopoly market can emerge in platform markets that are driven by a quality characteristic. However, demands and profits are severely skewed, such that the high-quality firm caters to the vast majority of agents (on either side) and recoups commensurate profits that vastly exceeds the profit of his competitor. Depending on the characteristics of passengers and transport firms market preemption is possible as well.

Zusammenfassung

Diese Dissertationsschrift befasst sich mit mehrseitigen Märkten vor dem Hintergrund vertikaler Differenzierung. Die Analysen erfolgen entlang dem Beispiel der Intermediation im Personennahverkehr. In einem ersten Schritt werden die Eigenschaften sowie die Entwicklung des Markts für Personenverkehrsleistungen in Deutschland betrachtet. Hierbei liegt der Schwerpunkt auf Marktakteuren, die zwischen den Interessen der Passagiere und der Transportdienstleister vermitteln. Namentlich sind dies Verkehrsgemeinschaften und Verkehrsverbünde. Darüber hinaus werden digitale Vermittlungsdienste betrachtet.

Auf Basis der historischen Entwicklung dieser erstgenannten Organisationen wird ein knapper Einblick in die Rechtslage der Marktintermediäre und die Rolle von Subventionen gegeben. Mit einer zunehmenden Orientierung an den Endverbrauchern bildete sich über die Zeit eine ganzheitliche Betrachtung der Verkehrsdienstleistungen, die beispielsweise auch städtebauliche oder ökologische Aspekte berücksichtigt. Aus diesem Grund stärkte die Gesetzgebung die Rolle öffentlicher Institutionen bei Intermediären. Diese Entwicklung führt zu einer vollkommenen MaaS-Sichtweise, in der konkurrierende private und öffentliche Verkehrsangebote durch einen Vermittler vermarktet werden.

Wie die vorliegende Arbeit zeigt, fördert der technische Fortschritt die Effizienz des Nahverkehrssystems und seiner Organisation. In den vergangenen 20 Jahren breiteten sich digitale Angebote zur Informationsbeschaffung oder dem Fahrscheinerwerb im deutschen Markt aus und stellen heute in den Ballungszentren den Marktstandard dar.

Da der Nahverkehr in den gesetzlichen Regierungsbereich der Länder fällt, wird dieser in einigen Bundesländern zentral organisiert. In anderen beschränkt sich

dagegen die Landesverwaltung auf den Eisenbahnregionalverkehr. In diesen Länder beauftragen die Kommunen jene Leistungen des Nahverkehrs, die über den Eisenbahnverkehr hinaus gehen. Dies führt beispielsweise in Bayern, Niedersachsen oder Mecklenburg-Vorpommern zu einem fragmentierten Nahverkehr mit vielen kleinen Verkehrsgemeinschaften und -verbünden im ländlichen Raum. Die Auswertungen zeigen, dass gerade diese kleineren Nahverkehrsregionen ein weniger ausgebautes digitales Serviceangebot vorweisen. Darüber hinaus zeigt sich, dass der Markt für Verkehrsleistungen dort weniger entwickelt ist, da hier das Angebot mit Zug- und Busverbindungen vollständig beschrieben ist. Dies bedeutet im Umkehrschluss, dass in diesen Regionen zum Beispiel keine oder nur wenige Sharing-Dienste aktiv sind.

Neue Arten der Personenbeförderung werden hingegen vorwiegend von privaten Unternehmen im städtischen Raum angeboten. Zu diesen zählen Car-Sharing, Leihfahrräder oder Mitfahrtaxis, bei denen das Fahrzeug mit anderen Passagieren geteilt wird. Wenn Anbieter dieser Dienste erstmalig den Markt betreten, werden solche Dienstleistungen meist direkt vermarktet. Mit dem Zugang zu einem Intermediär geht die Möglichkeit Verbindungen verschiedener Transportunternehmen zu kombinieren einher. Dies erinnert an die ursprüngliche Idee der Verkehrsverbünde. Allerdings übersteigen die Möglichkeiten einer Nahverkehrsplattform die der Verkehrsverbünde dahingehend, dass erstere auch nicht-öffentlich ausgeschriebene Verkehrsdienstleistungen und on demand Dienste anbieten können. Somit können Fahrgäste über weitere Verkehrsangebote informiert werden und ein höherer Grad an Markttransparenz wird erreicht. Dies kann wiederum durch sowohl das umfangreichere Angebot als auch die maßgeschneiderte Kombination von Verkehrsmitteln zu Fahrzeitreduktionen führen. Ergänzend kann der Intermediär dem Fahrgast helfen, jene Verbindung zu finden, die seinem Budget bzw. seiner maximalen Zahlungsbereitschaft entspricht.

Für Verkehrsunternehmen stellt ein Intermediär in erster Linie einen Absatzkanal dar, der mit steigender Nutzerzahl attraktiver wird und Vertriebs- bzw. Transaktionskosten reduzieren kann. Das heißt, je mehr Fahrgäste die Vermittlungsplattform rege verwenden, desto größer die Wahrscheinlichkeit für eine Transaktion mit dem Verkehrsunternehmen. Diese Abhängigkeit zwischen der Nutzerzahl der einen Marktseite und der anderen stellt eine (indirekte) Netzwerkexternalität dar. Der Intermediär nutzt diesen Effekt, um seine Dienstleistung zu verbessern und bezieht die Abhängigkeit der Nutzergruppen mit in seinen Preissetzungskalkül ein.

Da sowohl die Fahrgäste als auch die Verkehrsunternehmen von der Plattformnutzung absehen und statt dessen einen anderen Modus oder Absatzkanal nutzen können, wird diese Alternative in den folgenden Analysen betrachtet. Insgesamt stellt sich die Frage, welche Rolle Intermediäre einnehmen. Um dies zu bewerten, werden diese mit Blick auf Transaktionskostenreduktion, das Schaffen von geeigneten Vertragsverbindungen sowie das Schaffen von sofortigen Transaktionen anhand einer Literaturübersicht analysiert.

Untermauert wird die Diskussion durch ein einfaches Modell, das die Rolle des Vermittlers vor dem Hintergrund von Transaktionskosten und der Möglichkeit einer endogenen Nachfrage darstellt. In diesem Modell kommt es zu drei Marktsegmenten: Die Subjekte der beiden Marktseiten können zum einen den Intermediär beauftragen der garantierte Transaktionen zu einem festen Preis ermöglicht. Alternativ vertrauen die Subjekte auf einen Suchmarkt, bei dem die Zuordnung der Marktseiten zufällig erfolgt. In solchen Märkten können zwei Vertragspartner aufeinandertreffen, die zu keiner Verhandlungslösung kommen. Als dritte und letzte Möglichkeit können die Subjekte dem Marktgeschehen vollkommen fernbleiben. Zusammenfassend bietet dieser Ansatz somit ein geeignetes Instrument, um Intermediation grundsätzlich zu erklären, jedoch ist dieser auf einen Intermediär beschränkt.

Aus diesem Grund werden in einem weiteren Schritt alternative Ansätze zur Modellierung solcher Intermeditionsmärkte diskutiert, die auch den Wettbewerb zwischen Vermittlungsplattformen abbilden. Die zentralen Themenfelder stellen hierbei Differenzierung sowie Netzwerkeffekte dar. Bei ersterem liegt der Schwerpunkt auf vertikaler Differenzierung. Das heißt, die Unterscheidung von Produkt- oder Dienstleistungsanbietern wird durch ein Qualitätsmerkmal erzeugt. Dieser mit Blick auf die Marktstruktur vielfältige Ansatz ermöglicht es sowohl Monopolmärkte als auch Wettbewerbssituationen mit mehreren Konkurrenten zu analysieren. Unabhängig von der konkreten Marktsituation kann dabei die Nachfrage sowohl als exogen oder endogen modelliert werden. In Analogie zum vorangehenden Abschnitt wird dieser Ansatz ebenfalls durch ein allgemeines vertikales Differenzierungsmodell erläutert.

Darüber hinaus werden die grundsätzlichen Aspekte der Netzwerkökonomie besprochen. Dies schafft die Basis, um die klassische Unternehmensperspektvie bei der Diskussion der Differenzierung auf einen Intermediär und damit mehrseitige Märkte zu übertragen.

In Kapitel 5 werden konkrete Problemstellungen dieser durch Netzwerkeffekte bedingten mehrseitigen Märkte anhand einer Literaturübersicht diskutiert. Die zentralen Themen sind hierbei der Markteintritt in Plattformmärkte, wie mit asymmetrischen Marktstrukturen umgegangen werden kann und welche Schlüsse daraus in Bezug auf die Preissetzung gezogen werden können. Außerdem werden kartellrechtliche Herausforderungen besprochen, insbesondere auch vor dem Hintergrund der Marktabgrenzung. Erneut bildet eine Modelldarstellung den Abschluss des Kapitels. Hierbei wird ein erstes vertikales Differenzierungsmodell im Umfeld zweiseitiger Märkte aufgezeigt. Gleichzeitig motiviert dieses Modell eine tiefergehende Analyse, da die Annahmen des Modells äußerst stark sind. Daraus folgt, dass eine Übertragung des an dieser Stelle betrachteten Modells auf den Markt für Personennahverkehrsintermediation nur bedingt möglich ist.

Das anschließende Modell greift die vorangehenden Modelle auf und basiert maßgeblich auf dem vertikalen Differenzierungsansatz. Hierbei wird angenommen, dass die Plattformen in eine Technologie investieren, welche die Auswahl der Verkehrsmodi für die Fahrgäste optimiert. Gleichzeitig profitieren Verkehrsunternehmen von einem einfachen Zugang zum Kunden und sind bereit für diesen Zugang bzw. die Reichweite der Plattform in Sinne von zu erreichenden Kunden zu bezahlen. In Anlehnung an die Analysen der deutschen Marktlage, wo es Regionen mit einem einzelnen Intermediär, aber auch Regionen mit mehreren Plattformen gibt, werden bei dem Modell sowohl der Monopol- als auch der Wettbewerbsfall berücksichtigt.

Die Diskussion der Monopolplattform kommt zu dem Schluss, dass mit Bezug auf die Nachfrage vier mögliche Marktausprägungen existieren. Diese umfassen Kombinationen, bei denen Fahrgäste und Verkehrsunternehmen teilweise oder vollständig die Dienste des Monopolisten nutzen. Die daraus folgenden Marktsituationen bestimmen sich aus dem Gewinnmaximierungskalkül und hängen von den Charakteristika der beiden Marktseiten ab, die durch die Plattform verbunden werden. Das heißt, die Heterogenität der Nutzergruppen sowie deren Größe, bzw. deren Größenverhältnis bestimmen das vorläufige Marktergebnis im Sinne des Nutzungsverhaltens. Auf dieser Basis bestimmt der Monopolist letzten Endes die Höhe seiner Investition in die Vermittlungstechnologie.

Im Duopolfall ist die Zahl der möglichen Marktergebnisse höher. Grundsätzlich gibt es auf der Seite der Verkehrsunternehmen zwei Situationen: Zum einen können alle Unternehmen die beiden Plattformen nutzen, zum anderen kann ein Teil der Verkehrsleistungsanbieter der Plattformen fern bleiben. Darüber hinaus gibt es einen Sonderfall, bei dem der Qualitätsfolger, d.h. an dieser Stelle die Plattform mit einem kleineren Nutzerkreis auf Seiten der potentiellen Fahrgäste, einen künstlich niedrigeren Preis wählt. Dies führt zu einem Sonderfall, bei dem alle Verkehrsunternehmen durch die Plattformen erreicht werden.

Auf der Seite der Fahrgäste liegen ebenfalls die beiden Möglichkeiten des komplett abgedeckten Marktes sowie des Marktes vor, bei dem ein Teil der Nutzer die Plattformen nicht nutzen. Somit liegen insgesamt sechs Marktkonfigurationen vor.

Das Spiel der Intermediäre besteht aus drei Stufen: Im ersten Schritt konkurrieren die Plattformen über die Qualitätsausprägung, d.h. die Vermittlungstechnologie und damit die Höhe der Investitionen in diese. Es folgen im Anschluss die Preissetzungsspiele auf beiden Marktseiten. Um das Spiel zu lösen, werden die einzelnen Teilspiele beginnend mit dem Preissetzungsspiel der Verkehrsunternehmen rekursiv gelöst. In diesem werden für alle drei Marktergebnisse Gleichgewichte in reinen Strategien bestimmt. In den verbleibenden Teilspielen der Preissetzung für Fahrgäste sowie der Bestimmung des optimalen Investments können Gleichgewichte in reinen Strategien nur für die Marktkonfiguration bestimmt werden, bei der die Plattformen alle Verkehrsunternehmen und alle Fahrgäste bedienen.

Für die übrigen Kombinationen wird gezeigt, dass nur Gleichgewichte in gemischten Strategien möglich sind.

Insgesamt zeigt die Analyse, dass es in Vermittlungsmärkten, die durch ein Qualitätskriterium bestimmt werden, zu Duopolmärkten kommen kann. Jedoch sind in diesen Fällen sowohl die Marktanteile in Bezug auf die Nachfrage, als auch die Gewinne ungleichmäßig zwischen den Plattformen verteilt. Das bedeutet, dass die Hochqualitätsplattform einen deutlich größeren Marktanteil auf beiden Marktseiten bedient und dementsprechend auch einen Gewinn erwirtschaften kann, der den des Konkurrenten um ein Vielfaches übersteigt. Gleichzeitig zeigt die Analyse, dass in Abhängigkeit der Eigenschaften der beiden Marktseiten auch ein Monopol entstehen kann, da der Niedrigqualitätsanbieter aus dem Markt gedrängt wird.

1 Introduction

Along the growth of cities demand for transport rises. In ancient times, the population of even the largest cities lived within walking distance to their place of work, to markets and to leisure facilities.[1] Therefore, demand for structural personal transport systems was non-existent.

The need for new urban modes of transport developed as the size of cities grew in the second part of the last millennium. It was Blaise Pascal who had the idea of a coach-based line service in Paris. Together with the help of the Duke of Roannez, the marquis de Sourches and Pierre de Perrien, the marquis de Crenan, the three men initiated the *carrosses à cinq sols* (five-sol coaches) in Paris in 1662. For this service they obtained an exclusive licence by King Louis XIV. After the initial success, the upper class lost interest in the service while the middle and lower class rapidly abandoned it. They recognised, it was cheaper to walk than to use the coaches. Consequently, this first public transport project failed and was discontinued.[2]

With the Industrial Revolution, cities once again increased in both population and size. At the same time new forms of motorised transport emerged. While both the growth of cities and technological advances reinforced each other, the first lead to rising demand for transport and the latter supplied solutions for the inhabitants

[1] With its 1 million inhabitants and an extend of roughly 13 square kilometers, Rome was the biggest city of its time. Reinhardt (2018) defines 30 minutes as the limit for commuting by foot. At a speed of 5.4 kilometers per hour pedestrians could reach places that are approximately 2 kilometers away from their home within half an hour (taking into account for possible detours due to the city layout). Thus, for people living in the city center, this redounds to reaching all destinations within 30 minutes, as $\pi(2\ km)^2 \approx 12.6\ km^2$. See Reinhardt (2018, p. 17).

[2] See Moore (1902, pp. 3–7) and Vuchic (2007, pp. 8–9).

of cities. This was also the time when line services emerged and the first public transport systems were formed.

After WWII the development towards growing cities and rising demand for transport continued. Despite investments in infrastructure, volume in traffic increased. This lead to negative externalities in forms of pollution and congestion. New organisational structures for public transport were established to enhance efficiency and raise the number of passengers.

Today, the market for mobility soars and metropolitan areas continue to suffer from congestion and crowded public transit, i.e. travel demand rises, thus, transport capacities need to keep pace. Digital technologies and electric vehicles commence new forms of transport and ameliorate coordination between different modes. Given this supply side progress, the transport system as a whole becomes more involved and a greater variety of how to get form one place to another is placed at travellers' disposal. As the characteristics of all transport modes differ, for example, in speed, service level or comfort, travellers need to find and choose their optimal mode to conduct their ride given a cumulating supply of transport. For both passengers and transport providers, it remains to find an efficient allocation. Therefore, information asymmetries between them need to be challenged.

With the advent of mobile technologies, modern tools to obtain more detailed information on the possibilities of travel and its characteristics have increased in numbers. These tools include live information at stations as well as individualised smartphone apps. Partly, the applications and information given are supplied by transport firms themselves to market their service. In this case these firms are vertically integrated as they offer services beyond transportation. These apps inform passengers on the availability of the service, transport times and prices and contain payment solutions.

The problem is that each transport firm may provide its own app. Consequently, passengers need to install and apply multiple apps to obtain an overview on personal transport possibilities and, thus, the market.

Therefore, a second form of apps emerged. This form represents an intermediation service, which accumulates data from transport firms. The data is edited by the middleman and tailored to travellers' needs. The issue with information markets is that there are according to Shapiro and Varian (1999, pp. 24–29) only two viable market outcomes. For one, a monopoly market with a dominant firm offering information at lower cost than others. Second, a market with differentiated information that goes beyond a mere commodity. In the latter case, more than one intermediary could form the market creating competition.

The relevance of the topic to the general public is highlighted by Justus Haucap's presentation on mobility platforms in the German Bundestag. According to his statement, public transport firms should provide high quality data to improve the transport system and supply transport information to anybody. The aim in platform design should be to create a platform where private firms are willing to join and offer their data (on schedules and live traffic). In the same step Haucap warns that otherwise large tech companies could monopolise the market for transport information.[3]

In the personal transport sector, intermediation represents a means to improve the system. Middlemen have an extensive history in this sector, long before mobile technologies have advanced. Intermediaries have evolved after firms formed alliances and founded organisations managing marketing and coordinating transport supply. An example are public transport unions and alliances[4] that combine and reconcile different modes of transport by (possibly) different firms.

In Germany, these kinds of unions are widespread and have exceptional rights. Reasons for these rights are potent subsidies[5] and politically demanded service levels. Among these rights are relaxed antitrust requirements that explicitly allow for collusion among transport firms.

Over time, legislation on public transport changed and the seemingly vertically integrated structure of transport firms has mostly been cracked up. Thereby, the role of transport associations as a type of intermediary has gained significance.

[3] See Heute im Bundestag (hib) (2020).

[4] Some English literature also uses the German term "Verkehrsverbund" in this context. Cf. Pucher and Kurth (1995) or Buehler, Pucher, and Dümmler (2019) and Chapter 2.

[5] In Baden-Württemberg, for example, these payment exceed 200 million Euro per year. See Baden-Württemberg Ministerium für Finanzen (2019, p. 625).

As the word suggests, intermediaries stand between two parties moderating their interests and herewith generating value. Despite the people who look with a grain of salt on many intermediation services, as for instance, mortgage brokers, intermediaries can offer substantial benefits to their users. These include a place to trade where transactions can be made with low frictions and at high speed.

Modern day intermediaries can, furthermore, harness their demand from one market side to attract participants from the other side. Such demand interdependencies between, for example, transport providers and passengers are called (indirect) network externalities. Markets with these interdependencies are coined *two-sided markets* by Rochet and Tirole (2003). While these authors emphasise the role of the price structure in two-sided markets, others are less concerned and take the interdependence, exerted through their size between those parties, as reason enough to label such markets as two-sided.[6]

A vast majority of models on two-sided markets assume that both market sides can only interact through an intermediary. Outside options remain unconsidered. Therefore, demand on both sides is determined exogenously. However, as the transport case illustrates that passengers may refrain form using intermediation tools and just hop on a bus, whose schedules they know or just feel like taking it. In the same manner, there are passengers abstaining from commercial transport providers at all. They provide their own transport services instead, using a private means of transport. Examples are their car or bicycle. In that case, they obtain the transport service by supplying it by themselves.

To fill this academic void in this dissertation, a two-sided market model is developed including the choice of participation for both market sides, i.e. transport firms and passengers. In one-sided markets, vertical differentiation marks a parsimonious way to allow for different demand configurations. Therefore, this approach is transferred to the realm of two-sided markets, i.e. the network effect is interpreted as a quality criterion.

Going back to the analysis of the German market for transport intermediation, there are regions where only a single source offers information and ticketing to

[6] See e.g. Caillaud and Jullien (2003), Evans (2003a), Armstrong (2006) or Hagiu (2009).

passengers. In these markets *intermediaries* are monopolists. Therefore, it makes sense to analyse this market configuration first. In other areas (mostly metropolitan markets), multiple intermediaries compete. This motivates models in which passengers and transport firms can choose who's service (if at all) they want to use. Therefore, a duopoly setting is developed.

The central research question for these models is how these intermediaries set the prices they charge to both passengers and transport firms. In addition, these models include an exogenous quality measure that needs to be determined by the platform. Consequently, characteristics of both parties affiliated with intermediaries influence the market outcome. Their effects are analysed in detail.

The dissertation is compartmentalised according to these topics into three major parts. First, the German market for transport organisation and intermediation is empirically reviewed and presented together with selected characteristics of the active intermediaries. The analysis sets a focus on the digital agenda of transport firms' sales channels and the way these are organised. In this part the legal framework is briefly adumbrated as it explains the present state of public transport intermediation in Germany.

In the second part, the relevant economic literature is reviewed. The three main topics discussed are a) intermediation theory in a general setting, b) the role of non-price competition in terms of quality, i.e. vertical differentiation and demand externalities, i.e. network effects and finally, c) platform economics as the union of the former two. A few revered models are outlined putting their benefits and limitation in perspective to the research at hand. These reviews give a theoretical background for the discussion of the model followed in the final part.

At last, a model is presented that incorporates the identified voids in the literature against the background of transport intermediation. The basic idea of the model follows Roger (2017). However, it departs in large parts from restrictive assumptions on demand and specifically allows for market situations in which demand is determined endogenously instead of exogenously. This complies with the characteristics of transport markets. As announced above, the analysis is divided into two market configurations. Starting with a single transport intermediary, the pricing and quality choice game is amended by competition in a duopoly setting to illustrate the effects of competition. The dissertation concludes with a discussion of the results given on transport intermediation and hints towards other fields where a model of two-sided intermediation with vertical differentiation can be applied.

2 Demand for travel intermediation

Modelling travel demand originated in the middle of the last century as individual transport became feasible for the masses. The volume of trips increased and negative externalities appeared in forms of traffic congestion and both air and noise pollution. Motivated by these market distortions researchers started to analyse these problems and to find the levers that influence urban travel.

The first transport models of the 1950s focussed on demand for mobility.[7] Therefore, a zonal approach was developed to record real life travel behaviour. That means, the analysed area was compartmentalised into zones. Based on these zones interviews were conducted and questionnaires were distributed. The population was asked about their trips and, consequently, about where they depart and where they are heading. Thereby, all zones passed along the way of a traveller were noted. Finally, the researchers collected all data and obtained a network of travel flows. This allowed them to forecast demand for travel, deduce answers for their research or to consult the government on infrastructure planning.[8]

In the 1970s, this approach was refined by adding some economic reasoning. Specifically, utility theory was applied to the transport analysis and it was made the central determinant of travel. The idea was to take travellers' point of view in order to maximise their utility obtained from conducting rides. The fundamental assumptions for utility maximisation are travellers' rational preferences, in terms of completeness and transitivity. Given these preferences, a utility function can be

[7] See e.g. Black (1981, p. 97).
[8] See also Hensher (1977a, pp. 81–82).

set up and the problem for travellers can be stated as a maximisation problem on the consumption set given travellers' budget constraints.[9]

Unfortunately, preferences of consumers are unavailable to the modeller of travel demand.[10] Instead of a preference-based approach, a choice-based approach is applied to model utility maximisation.[11]

This approach became the standard in transport research to analyse consumer's decision in a literal sense, i.e. characteristics of travel decisions are treated each on a separate level. However, the set of possible alternatives in travel is vast for both travellers and researchers. This requires particularly the latter to structure the problem.[12] Domencich and McFadden (1975, pp. 33–46) establish a "Theory of individual travel demand" based on six stages to structure travellers' decision problems. Figure 2.1 illustrates these six stages suggested by Domencich and McFadden.[13] The stages are hierarchised by their impact on travellers' lives starting with the choice of living and working. This sets the basis for all following decisions. Vehicle ownership, as the second decision stage, represents a lower commitment: buying or selling a car is associated with less effort than moving to another place. The remaining decisions are about the trip itself, i.e. making a trip at all, where to go, when to travel and at last by what means.

As Figure 2.1 suggests by bidirectional arrows, all of these choices are dependent on each other. Each stage might be reconsidered after an intermediate decision has been reached. Especially, the last four stages can be seen as a simultaneous decision by travellers.[14]

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[9] See Mas-Colell, Whinston, and Green (1995, pp. 42–63) and Woeckener (2014a, pp. 38–44).

[10] This problem is not limited to transport research, but transfers to other areas, as well.

[11] See e.g. Mas-Colell et al. (1995, pp. 91–92) for a proof that the two approaches lead under the strong axiom of revealed preference to the same results.

[12] Cf. McFadden (1974, p. 314) and Domencich and McFadden (1975, pp. 38–39) for an illustrative example.

[13] There are other ways to analyse transport. One of these includes splitting up the decision process into four groups that include trip generation, its distribution, the decision of a mode and finally the route of the trip. See e.g. Oppenheim (1995, pp. 11–16).

[14] See Domencich and McFadden (1975, pp. 35–43) and Ben-Akiva and Atherton (1977, p. 226). Furthermore, it can be noted that this modelling approach is not unique. For example Black (1981) summarises and categorises modal choice models in classical travel demand models into four types. Each of these differs in the stage, where a mode is chosen. Namely, the mode can be chosen concomitantly with trip generation, or in sequence to trip generation. Alternatively,

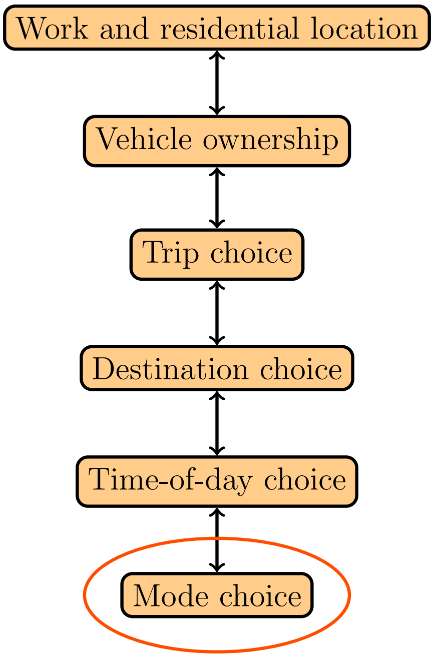

Figure 2.1: Decision ladder in personal transport

Own representation based on Domencich and McFadden (1975, p. 43).

In the following, the issue tackled is not so much about the actual choices made by passengers, but about how these choices are made. That means, what information do travellers need and who supplies this information in which way. Therefore, the analyses below depart form the transport literature and tools of transport engineers. In contrast, they focus on mode choice and further aspects of travel not captured by the *traditional* fashion.

In the present context, the term mode refers to the way of transport that can be distinguished from others by the infrastructure it needs, the vehicles and their drivers as well as the propulsion system used.[15] Passengers are assumed (similarly to Domencich and McFadden) to behave according to some utility mapping. This results in a measure for surplus. The surplus depends on an information service level and the price associated with it. The service level can be interpreted as the gross benefit passengers achieve in comparison to a situation where they are devoid

mode assessment can be modelled to be simultaneous to trip distribution or, finally, in between trip distribution and traffic assignment.

[15] For a detailed discussion of modes cf. Vuchic (2007, pp. 45–90).

of such information. Prices may be stated in any currency plus the cost for the effort associated with the service.

The relevance of such an issue may be trivial for habitual rides. Nevertheless, the issue of imperfect knowledge has many aspects. These comprise a lack of knowledge on substitute services or transport possibilities as well as on prices of rarely used services and even on the precise characteristics of alternatives, as for example, comfort or punctuality. The latter are crucial attributes in the transport setting.[16] Most prominently, this problem occurs to travellers when they arrive at an unfamiliar foreign place, as for instance, a distant airport. Travellers want to get to the city center, but are unaware of the means that can get them there. Therefore, travellers can for example approach the ticket machine at the subway station, the clerk of rapid bus system, the clerk for public bus transport or taxi drivers. After getting acquainted with the systems and the (expected) prices charged, the traveller can make his optimal choice according to his preferences. In contrast to this trivialised laborious process, a traveller can also decide to ask a third party for advice. Traditionally, tourist information desks offer this service. With modern technology, smartphone applications can offer the same service, but are also prone to unfamiliarity themselves. Which is tantamount to non-zero search cost. Sticking to the example of unfamiliar tourists, these may not be poised to assess the supply of mobility apps after an exhausting flight. Thus, decisions on which platform to use or which app to install represents a friction, too.[17] But it can be assumed that some travellers will waive the option of utilising such services.

Nevertheless, the argument of reduced effort is supported by e.g. Viergutz and Brinkmann (2018). They suggest that for unfamiliar travellers a mobile information and ticketing tool is most helpful. During their analysis of data on how travellers obtain information for their travel decisions, they foremost notice that travellers regularly use mobile applications and tools when gathering information on possible rides. Against intuition, the frequency with which they use an information intermediary is positively correlated with the usage of public transport. Thus, presumably

[16] Cf. Chamberlin (1965, p. 118).
[17] See Haucap, Pavel, Aigner, Arnold, Hottenrott, and Kehder (2017, p. 166).

well informed travellers demand additional live data. This can be explained by the surplus they enjoy when consuming the data and the data's quality as the degree of imperfect knowledge decreases.[18]

To sum these points up, the actual question is, how can transport intermediaries help travellers make informed decisions and, thereby, create value to their customers? However, not only travellers benefit from intermediaries, but their services can be of great avail to transport firms as well. For example, more efficient sales mechanisms can be offered that proof to be cheaper than existing solutions. In addition, entry to a larger customer base and provisioning of data to improve business processes represent further instances of how intermediaries can create value for this group. To better comprehend the role of an intermediary in the transport setting, it is helpful to look at transport intermediation in its entirety an how it developed. In the next sections the process and motivation to form such services or organisations is described together with the status quo of their design and their legislation.

2.1 Development of transport intermediation

2.1.1 Transport associations

In the late 1960s, the concept of transport associations was created. It rests on transport firms within a conurbation that decide to consolidate different modes of transport and the services of various competing providers (of the same mode).[19] Thereby, uniform tariffs and a coordinated timetable could be formed enabling comfortable intermodal traffic. The motivation behind this step is to make all services more attractive. That means, travellers will benefit from better service while simultaneously transport firms economise on increased demand. Consequently, a transport association creates a win-win situation for both market sides.

[18] See Viergutz and Brinkmann (2018, pp. 336–341) Schelewsky (2013, p. 313) and Beul-Leusmann, Samsel, Wiederhold, Krempels, Jakobs, and Ziefle (2014, pp. 217–218).
[19] Cf. Vuchic (2007) for more on personal transport before 1960.

Since the founding of the first association the legal framework has been changed and adapted to the benefits it creates. Therefore, the structure of these organisations has shifted to a more public state, i.e. regulators became aware that these institutions hold power to shape urban traffic and, consequently, have an impact on land use. By conditioning subsidies on administrators' demands, the associations started to partner with local governments. By the time, public tendering of transport services lead to less power of transport firms and, nowadays, many associations are mainly governed by local administrations. Beyond this, the concept of an association requires coordination, which is too costly for some transport firms and therefore less integrated forms have been established, too. These forms of intermediation can mostly be found in rural and less populated areas.

Aims and structure

The general idea of a transport association was to simplify travellers' lives by offering simple tariffs, lower prices and coordinated connections. Thereby, transport firms hoped to attract more consumers to augment vehicle occupancy and, ultimately, to increase profits.

The very first association was the *Hamburger Verkehrsverbund (HVV)* founded in 1965. It comprised the *Hamburger Hochbahnen AG*, *Hafendampfschiffahrts-Actien-Gesellschaft (HADAG)*[20], *Deutsche Bundesbahn* (today *Deutsche Bahn (DB) AG*) and five smaller rail and bus companies.[21] The firms and city government identified problems for both passengers and transport firms and, thus, society as a whole. These problems included a lack of integration between operators leading to long travel times, unnecessary transfers and costly rides for travellers. Consequently, inhabitants refrained from public transport and switched to other modes, foremost individual motorised transport. This shift to automobiles is well documented by the statistics on vehicle ownership. In Hamburg the population owned around 42 cars

[20] Today, HADAG is no longer used as an abbreviation but only as a solitary name.
[21] These smaller firms together made up for only less than 6 percent of passengers carried in 1970.

per 1,000 inhabitants in 1955. At the time the *HVV* was introduced, this number more than quadrupled to 174.[22]

The motivation for transport firms followed from competition. On some lines their services were overlapping. This lead to low occupancy rates in vehicles. In total, the aim of coordinating transport supply was to increase efficiency of the transport system in the metropolitan area of Hamburg.[23]

Despite the convincing arguments in Hamburg's case, there are many associated questions that need to be solved in advance and during operation:

- Foremost, the distribution of revenues among transport firms and financing of the association itself.[24]
- Operational adjustment of timetables to minimise waiting times for transferring passengers while considering physical and legal constraints. Obligatory breaks for bus drivers are an example.
- Long-term planning.

For these tasks, the analysis described above of the trip distribution and the traffic flows are essential.

By the time the concept has proved its value as service qualities in terms of geographic extend, speed and integration of intermodal transport increased rapidly. Attractive price systems and targeted marketing lead to surging passenger numbers. Thus, similar thoughts were established in other regions and cities. Among these were Hanover, Munich, Frankfurt and Stuttgart. All of those established transport associations during the 1970s.[25] Today, transport associations are common in all major German cities and even in some rural areas as Chapter 2.2 and Appendix A below explicate.

In smaller and less populated regions, where public transport is organised by local transport firms themselves, the frictions to consolidate and coordinate are higher

[22] See Homburger and Vuchic (1972, pp. 84–87).
[23] See Homburger and Vuchic (1972).
[24] Cf. Homburger and Vuchic (1972, p. 90) and Glaser (2009).
[25] See Pucher and Kurth (1995, pp. 280–287).

despite lower participation. Reasons for this lie in the monopoly power of the few firms involved and the limited market size. However, the benefits of coordinated timetables, in terms of increased demand by travellers, incentivise transport firms to organise routes and departing times together. Such arrangements are termed *schedule unions*.[26]

A different approach to enhance the services offered by multiple transport firms is to collude on prices making the market more transparent. Offering the same tariff an all routes decreases information demand by travellers, since the same information can be used for all participating transport means. In transport parlor, these unions are called *tariff unions* or *fare alliances*.[27]

Depending on the contractual specifics between the partnering transport associations, a tariff union may either be limited to the same price system, i.e. same price per distance or may even include a clause that tickets of competing transport firms are accepted. Thus, a single ticket can be used on vehicles of different transport firms. From an organisational point of view, this requires far more involved contracts since revenues may be largely collected by one firm while the others sells less tickets. This could lead to a situation, where the majority of passengers may have bought their tickets from the competitor. Therefore, transport firms need to negotiate fair terms and develop ways to determine the size of compensations.[28]

Combining the two forms of schedule and tariff unions leads to *transport unions*. That means, the partnering transport firms collaborate with regards to schedules, line planning and tariffs.[29]

Increasing cooperation between transport firms leads back to the case of Hamburg and its transport association. To delimit a transport union form an association, the collaboration includes a separated organisational unit. The responsibilities of this unit include planning, schedules, price system, public relations, passenger information and marketing.[30]

[26]See Krause (2009).
[27]See Gehrmann (2009, p. 51).
[28]See Fischer (2005) and Glaser (2009).
[29]See Reinhardt (2018, pp. 574–575).
[30]See Krause (2009), Schmidt-Freitag (2009, pp. 124–126) and Reinhardt (2018, p. 575).

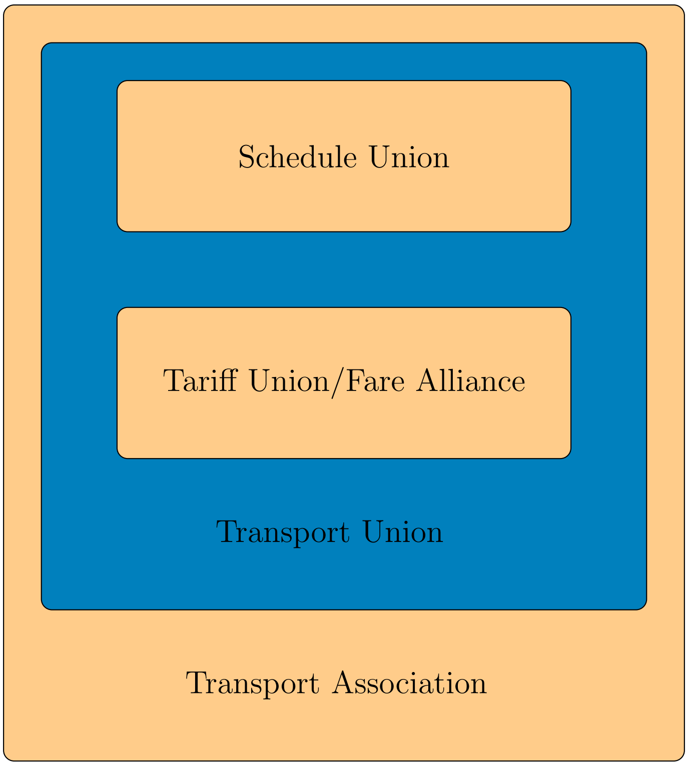

Figure 2.2: Collaboration in public transport

Own representation based on Krause (2009).

To illustrate this pattern Figure 2.2 summarises the scope of collaboration among the forms of public transport organisation. While cooperation among transport firms is limited to timetables or tariffs at the inner layers of the graph, transport unions and transport associations encompass both tasks. The difference between the latter two types lies in a separate unit that administers organisational tasks of the transport services offered in the case of associations.

2.1.2 Legal framework for public transport in Germany

Since public transport represents services provided to increase the mobility of all citizens, governmental funds are used to provide and improve these services.[31] Legislators on different levels have passed laws to both comply with general public interests and to earmark funds economically. These laws aim at characteristics of public transport and are designed to introduce allocation by market force rather than by traditions and fiat. Most notable are the laws on competition policy in public transport (European Union (EU) regulation 1370/2007) and laws specifically aimed at the responsibilities of public transport (Regionalisation Act[32] and state-level public transport laws). These two lines of legislation are adumbrated in the following paragraphs to help understand the status quo in transport. Special attention will be given to the role of intermediaries and regulations with regards to sales. Competition concerns between suppliers go, however, beyond the present scope.[33]

Starting with European legislation, EU regulation 1191/69 was replaced by EU regulation 1370/2007. It specifies the terms of procurement in public transport. This includes the responsibilities as well as exceptions from tendering.[34] In addition,

[31] See e.g. Pucher and Kurth (1995, pp. 287–290).

[32] In German coined Regionalisierungsgesetz (RegG).

[33] With regards to cooperation in public transport, especially to ensure harmonised schedules and uniform tariffs, § 8 section 3b) German Transport Law (Personenbeförderungsgesetz (PBefG) makes an exception to anticompetitive agreements, i.e. § 1 German Antitrust Law (Gesetz gegen Wettbewerbsbeschränkungen) does not apply to such agreements. As Weißkopf and Mäder (2009, 108–109) explicitly describe it, transport associations have to be considered to be cartels.

[34] These exceptions are largely based on low volumes in terms of revenue generated or when the responsible authorities provide the service by themselves.

it requires annual disclosure of the public service obligations by the corresponding authority. Thereby, "performance, quality and financing of the public transport network can be monitored and assessed" and the reports "provide information on the nature and extent of any exclusive rights granted."[35]

On the national level, the PBefG refined these European provisions. The law is limited to transport by passenger cars, buses and light rail. Tenders may include both construction and operation as well as design and management of lines.[36] Furthermore, § 12 and § 39 PBefG elaborate on pricing. Important points are that fares need to be enclosed when applying for licenses and that changes of these fares need to be approved by authorities. Thus, discounts and premia are according to § 13 section 3 PBefG due to notification (to authorities) and must be accessible at equal terms. To what extend these restrictions affect intermodal transport remains open. Examples are transport options that include both public and private ventures. This impacts bundling possibilities for ticketing, i.e. combinations of multiple tickets into one ticket, too.

The amendment in 1993 of the German Railway Act[37] together with the concomitant introduction of RegG redefined the responsibilities of public transport provisions and the authorities mentioned in the previous paragraph. Essentially, responsibilities for public transport where defined to be on state level and the states receive compensation for their efforts by the federal government.

These regulations are extended by state law. There, the dualism between railway and bus systems is kept, such that tendering and administering railway services remained at the state level (mostly at the transport ministries). This was justified by the cross-regional significance of most railway lines and still marks the status quo. For non-rail services, many states delegated these tasks to districts and urban municipalities or to existing organisations and administrative unions, such as transport associations.

[35] See article 7 EU regulation 1370/2007 and note that tendered public transport services are de jure protected from direct competition for the duration of the tendered contract.
[36] See § 9 PBefG.
[37] In German denoted by Eisenbahnneuordnungsgesetz (ENeuOG).

2.1.3 Changes in transport intermediation

Due to subsidies and planning possibilities the RegG shifted power from transport firms to state or local government. In sequence, the monopoly power of incumbent transport firms for line services has been reduced, as this power is now due to tendering. This means, firms need to compete for service contracts of line services. Consequently, tendering can lead to market exit of established transport association members losing lines to new firms that enter the association's purview.

To account for this change in legislation, the concept of transport associations has shifted from a company-centered alliance to an authority centric alliance. In an authority alliance the governments of municipalities, counties or states constitute the association's board while transport firms are demoted to partners. Given the strong dedication by authorities, public spending increases and infrastructure is modernised leading to more users of the association's services.[38] This shift occurred in the 1990s. By the same argument, Reinhardt (2018, p. 574–575) expects firm-owned transport unions to vanish in their previous form and being replaced by an authority lead union due to the consequences of the RegG.

Figure 2.3 illustrates the difference between the generations of transport associations. It includes the latest development of associations. The third generation of transport association is characterised by increased competition among transport firms. For the association the service level provided becomes a central aspect to decrease individual motorised transport. As Sparmann (2009, pp. 210–211) emphasises, an associations becomes a marketplace for mobility. This means, the relationship between passengers and the association intensifies, since customers interact mainly with the intermediary who reduces entry barriers by offering new technologies for information and sales. Therefore, the role of transport firms is once again demoted. In addition, the association is responsible for all marketing activities and it integrates new forms of mobility providing better intermodal transport and utilising the benefits of all modes improves passengers' welfare.

[38] See Sparmann (2009, pp. 210–211).

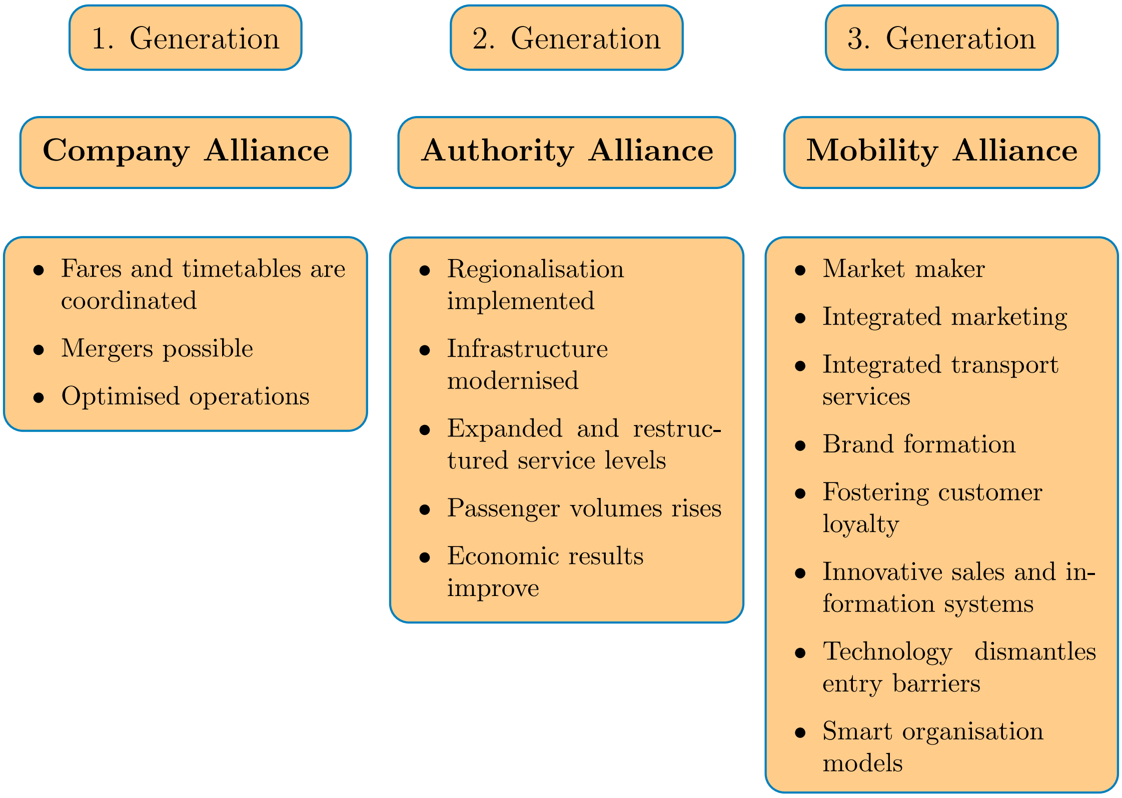

Figure 2.3: Generations of transport associations

Own extended representation based on Sparmann (2009).

Nevertheless, legal obligations remain at transport associations. Therefore, issues on land use and consequently licences on lines and routes offered are still administered by the intermediary.

This last generation of transport associations is closely related to the concept of MaaS. In the next section, this service-centered view on mobility suggested by MaaS is explained in more detail.

2.1.4 Mobility-as-a-Service

Digital and mobile intermediaries are termed MaaS[39] as they provide services around trips instead of physically providing transport. According to MaaS-Alliance (2018), "MaaS is the integration of various forms of transport services into a single mobility service accessible on-demand." This redounds to a very general understanding of mobility services, as for example, ticketing machines nowadays include routing and mode choice. The overlap to transport associations of the third generation is, consequently, large. Hence, other authors are more restrictive demanding a mobile device to comply with the *on-demand* requirement or even limit MaaS to certain tariff structures of mobility.[40] However, many authors see the connection that MaaS-providers establish between travellers and transport firms or transport service providers. They describe the benefits brought to either group.[41] Hensher (2017) describes MaaS in a functional way as the "3Bs": budgets, bundles and brokers. These three components address heterogeneous price elasticities of travellers, possibilities to create travel chains including various means of transport and finally the role of a market maker for personal transport.

Looking at travel data in Finland, Haahtela and Viitamo (2017) have derived needs of travellers on MaaS. Most importantly, they note that "all the different modes of transport" are to be included in a mobile solution and that the solution contains a payment option for the whole trip. In addition, the authors describe real

[39]In the American literature, MaaS is also known as Transport as a Service (TaaS).
[40]See Kamargianni and Matyas (2017, p. 4) and Li and Voege (2017, pp. 97–101).
[41]See MaaS-Alliance (2018), Kamargianni and Matyas (2017, p. 6–8) and Smith, Sochor, and Karlsson (2018).

time data and an "[e]nhanced travel chain optimizer", which reduces travel time by choosing and combining different modes together with additional information on prices and on carbon emissions, as vital.[42] In the following, the understanding of MaaS will be linked to the definition by Haahtela and Viitamo (2017) offering a rather broad scope.

2.1.5 Legal framework for electronic information and intermediation services in transport

Directive 2010/40/EU of the European Parliament and of the Council specified aims to increase efficiency, safety and the ecological impact of the transport infrastructure (especially to road usage). Therefore, article 1 states that the "Directive establishes a framework in support of the coordinated and coherent deployment and use of Intelligent Transport Systems (ITS) within the Union, in particular across the borders between the Member States, and sets out the general conditions necessary for that purpose." In the subsequent articles priorities are given, stating first the use of transport data and "EU-wide multimodal travel information services"[43] before other aspects of the aims. The scope of these ITS with regards to information focuses on demand of information needed before and while travelling "to facilitate travel planning, booking and adaption."[44]

Actions to achieve these aims are specified in the EU Regulation 2017/1926. Here, links to other regulations and aims, which are complemented and/or affected, are described in detail. Prominent examples are the Trans-European Transport Network (TEN-T) specifying European transport infrastructure as a whole and the Connecting Europe Facility (CEF) for the transport sector providing financial assistance.

However, the question whether and how to implement the regulation is left to national governments.[45] Once a decision on the implementation has been achieved,

[42]See Haahtela and Viitamo (2017, p. 287).
[43]See article 3 Directive 2010/40/EU.
[44]See article 4 Directive 2010/40/EU.
[45]See article 5 EU Directive 2010/40/EU and preface to EU Regulation 2017/1926.

the "data for the provision of comprehensive travel information services [... should be] accessible to users through a national or common access point".[46] This data has to include static data and its related metadata. It needs to be provided by transport authorities, transport operators, infrastructure managers and other transport service providers.[47]

Under article 4 EU Regulation 2017/1926, the EU has defined a timeline to implement parts of the access points. The first service level is to be accessible on 1 December 2019 and includes:

- Location search.
- Trip plans.
- Access nodes.
- Trip planning for schedules modes of transport.
- Trip planning for road transport including personal rides, cycle networks and pedestrian networks including accessibility.

The second service level should be implemented one year later by 1 December 2020. Beyond the points of service level 1, it requires:

- Location search to find access points to demand-responsive modes including park&ride stops, bike and car-sharing stations, refuelling and charging stations as well as secure bike parking facilities.
- Information service on payment services for both direct transport services, such as (public) line services or on-demand services and indirect services, e.g. parking.
- Trip plans, auxiliary information, availability check.

By 1 December 2021, the third service level should be accessible. It includes:

[46] Point 10 of the preface to EU Regulation 2017/1926.
[47] See point 10 of the preface to EU Regulation 2017/1926.

- Detailed common standard and special fare query.
- Information service (all modes).
- Trip plans.
- Trip plan computation.

However, these dates refer to the *comprehensive TEN-T*,[48] i.e. the main infrastructure network within the EU. For the remaining parts of the transport network, the regulation demands implementation by 1 December 2023.

Despite the focus of EU Regulation 2017/1926 and the corresponding parts of EU Directive 2010/40/EU on information services, the intermediation businesses considered vastly build on this information. These platforms use data by transport suppliers (specified by the three service levels) and provides an additional layer for travellers to purchase tickets and for suppliers to include their distribution channels.

2.2 Transport intermediation in Germany and their digital agenda

As of 2021, there are more than 121 transport associations, regions and unions in Germany. The design of these differs among states and there is no legal requirement to the extend of cooperation and integration of the associated transport firms. The extremes reach from Berlin and Brandenburg, where a single association covers the whole city and its neighbouring state, to the fragmented public transport in Bavaria or Lower Saxony. In these states, public bus transport is administered and tendered by counties while only rail services are tendered and organised by state authorities.

In the following, the 16 German federal states are analysed in alphabetical order with regards to their organisation of public transport and the status quo of their digital development, especially, online payment integration is assessed.

[48] Cf. EU Regulation 1315/2013.

2.2.1 Baden-Württemberg

According to Baden-Württemberg's public transport law (BW ÖPNVG), responsibilities for line services are divided between the state and the districts. This means, the state is responsible for railway services while the districts and counties assign and tender bus contractors and other forms of line service. Section 9 BW ÖPNVG demands, furthermore that transport services cooperate between the districts. Namely, it suggests the initiation of transport associations. This concept of transport intermediation was introduced in the late 1970s. The first three transport associations in Baden-Württemberg are today's largest associations by both passengers transported and area covered. As a result of their success and due to political support, more and more association were founded.

Today, all of Baden-Württemberg is covered by transport associations or unions. These associations often represent multiple districts. In Table 2.1 the 21 transport regions organising public transport are listed.[49] The idea of cooperation between districts has been extended to neighbouring states and countries to account for cross-border demand. Six associations partner with regions outside Baden-Württemberg. Furthermore, the state's transport ministry helps to facilitate public transport across the whole state. Therefore, the initiative *bwegt*[50] was founded. It offers simplified tariffs for rides beyond transport associations' limits covering the whole state. Today, it offers an app supplying both detailed information on prices and schedules (including live data). Both the app as well as *DB Navigator* offer mobile tickets for *bwegt*-tariffs. However, not all fares that are applicable for rides within a transport association are supported.[51]

Nevertheless, public transport and its organisation within the associations are subject to the regions' responsibilities. This includes passenger information and sales policy. Of these 21 transport regions 19 are organised as transport associations and the remaining two as transport unions. While *Verkehrsverbund Stuttgart (VVS)*

[49] The 22nd association *Filsland* dissolved and was integrated in late 2020/early 2021 into *VVS*.
[50] The word *bwegt* is a portmanteau of the initials of Baden-Württemberg and the word *bewegt* meaning *in motion* in German.
[51] These tariffs are also promoted under the name *bwtarif*.

Table 2.1: Transport regions in Baden-Württemberg

Transport region		Population*	Passengers per year*	Transport firms*
bodo	*Bodensee-Oberschwaben Verkehrsverbund*	582K	40M	22
DING	*Donau-Iller-Nahverkehrs-verbund*	650K	<61M	34
HNV	*Heilbronner-Hohenloher-Haller Nahverkehr*	581K	48M	22
htv	*Heidenheimer Tarifverbund*	132K		6
	KreisVerkehr Schwäbisch Hall	196K	17M	9
KVV	*Karlsruher Verkehrsverbund*	1.4M	166M	33
naldo	*Verkehrsverbund Neckar-Alb-Bodensee*	834K	73M	53
	OstalbMobil	314K	20M	23
RVF	*Regio-Verkehrsverbund Freiburg*	658K	123M	18
RVL	*Regio Verkehrsverbund Lörrach*	229K		8
TGO	*Tarifverbund Ortenau*	430K	37M	9
TUTicket	*Verkehrsverbund Landkreis Tuttlingen*	140K	9M	5
VGC	*Verkehrsgesellschaft Bäderkreis Calw*	158K		10
vgf	*Verkehrs-Gemeinschaft Landkreis Freudenstadt*	122K		14
VHB	*Verkehrsverbund Hegau-Bodensee*	285K	19M	11
VPE	*Verkehrsverbund Pforzheim-Enzkreis*	325K	33M	15
VRN	*Verkehrsverbund Rhein-Neckar*	3M	310M	58
VSB	*Verkehrsverbund Schwarzwald-Baar*	212K		15
VVR	*Verkehrsverbund Rottweil*	140K	9M	15
VVS	*Verkehrsverbund Stuttgart*	2.5M	384M	45
WTV	*Waldshuter Tarifverbund*	171K	18M	4

*These numbers are based on different sources found in the text below and in Appendix A.1. For empty values no figures were published in the last years.

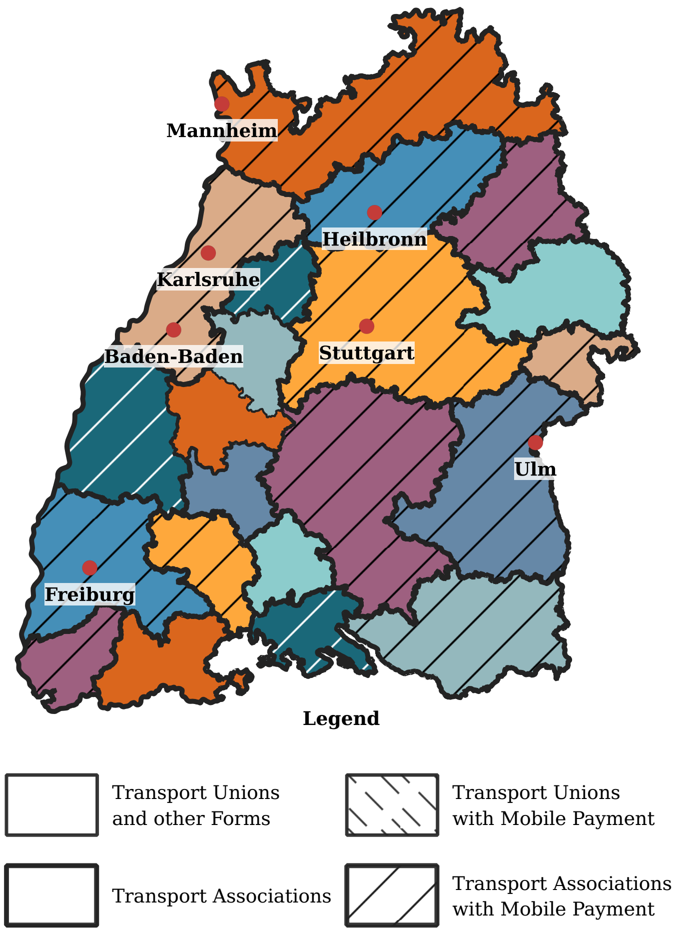

Figure 2.4: Transport intermediaries and mobile payment solutions in Baden-Württemberg

The geographical data processed in all maps is based on raw data by Bundesamt für Kartographie und Geodäsie (BKG) (2018).

Table 2.2: Mobile ticketing applications in *Verkehrsverbund Rhein-Neckar*

App Name	Routing	Live Data	Check-In/Check-Out/Be-Out	Provider
myVRN	✓	✓	✗	*Mentz*
VRN-Ticket	✓	✓	✗	*HaCon Ingenieurgesellschaft*
rnv/VRN-Ticket	✓	✗	✗	*EOS Uptrade*
DB Navigator	✓	✗	✗	*DB*
eTarif	✓	✓	✓	*SevenRe*
Tickin	✗	✗	✓	*DB*

was among the first transport associations that were founded in the 1970s, most associations in Baden-Württemberg were organised in the late 1990s and noughties. These regions are depicted in Figure 2.4. Both the delimiter and colour indicates whether a region is organised by a transport association or not. Bold edges and dark hues mark transport associations while narrow edges and pastel-coloured areas denote transport unions and other forms of transport organisation. Within these associations and (in Baden-Württemberg's case) unions up to almost 60 firms provide (public) transport services.

As Table 2.1 indicates, both this number of transport firms as well as the number of conducted rides differs among the regions. In the same manner the digital service scope differs. Generally, 15 of the 21 regions offer mobile ticketing. This is indicated by the hatching of the areas in Figure 2.4: straight hatching form the bottom left to the top right indicates that the region offers mobile ticketing and is organised by a transport association. In Baden-Württemberg, *Donau-Iller-Nahverkehrsverbund (DING)* was among the first organisations offering a mobile sales channel in 2007. In the more densely populated areas there are, nowadays, multiple apps to purchase different kind of tickets. With for example check-in/check-out systems in *KreisVerkehr Schwäbisch Hall*, innovative check-in/be-out in *Verkehrsverbund Rhein-Neckar (VRN)* or the *Home Zone* with a flat-rate for short rides by *Karlsruher Verkehrsverbund (KVV)*, a versatile supply of mobile ticketing systems is offered.

The descriptive analysis and the illustration in Figure 2.4 show that there are services that market transport services to travellers. However, both lack a view on the number of applications offered and thereby a view on competition among such services. The in-depth discussion of these regions in Appendix A.1 give details on these services. An example for a broad supply of digital services is *VRN*. Table 2.2 lists these offering along the firms that operate these apps.

In general, larger and long-established associations offer more mobile services both with regard to services included in terms of transport modes and with regard to the number of apps offered.

2.2.2 Bavaria

In Bavaria, there are nine transport associations and more than 20 transport and tariff unions.[52] Many of Bavaria's rural areas lack such cooperation, thus, public bus transport is provided by few individual firms. In line with EU regulation 1370/2007[53] and the Bavarian Public Transport Law,[54] bus services are commissioned by local authorities. State government, on the other hand, puts rail services out to tender. Accordingly, these services are organised on state level for all regions within Bavaria.[55]

BayÖPNVG demands cooperation between local authorities and encourages to form transport unions and associations. The nine existing transport associations in Bavaria are listed in Table 2.3. Furthermore, local authorities are advised to offer tariff options for transport between public transport areas.[56]

To illustrate the state's transport landscape Figure 2.5 maps all Bavarian transport regions. The nine transport associations are accentuated by dark colours and bold edges. Seven of these associations supply services for mobile payment.

[52]The data on these numbers vary from source to source (see e.g. DB Vertrieb (2020) with seven, DB Regio Bus Bayern (2020) with six or Bayerisches Staatsministerium für Wohnen, Bau und Verkehr (2020) with only five listed associations). The numbers provided here are based on the extensive analysis in Appendix A.2.
[53]Cf. Chapter 2.1.2.
[54]In German Gesetz über den öffentlichen Personennahverkehr in Bayern (BayÖPNVG).
[55]See sections 6, 8, 9 and 15 BayÖPNVG.
[56]See section 7 BayÖPNVG.

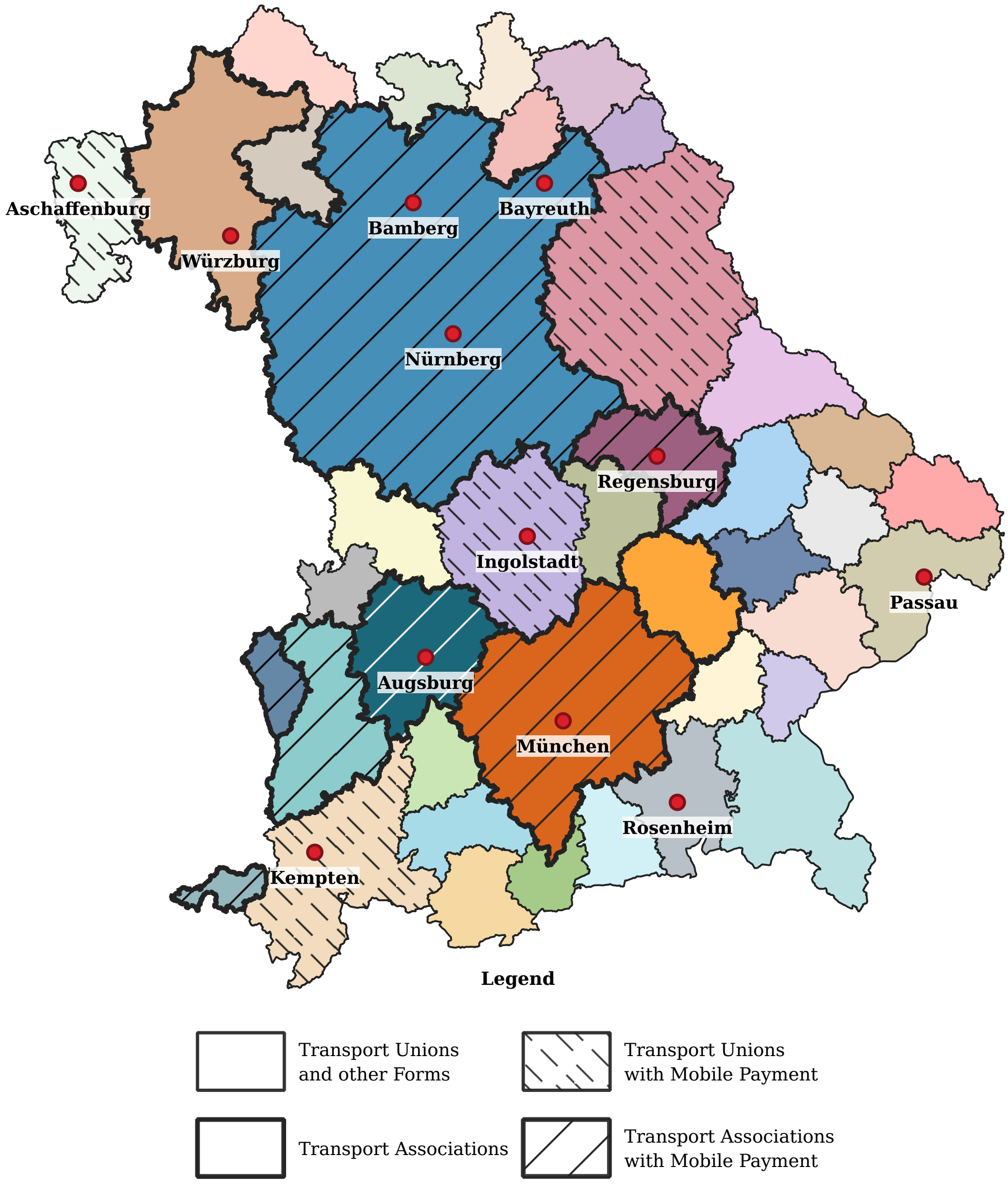

Figure 2.5: Transport intermediaries and mobile payment solutions in Bavaria

Table 2.3: Transport associations in Bavaria

Transport association		Passengers per year*	Transport firms*
AVV	*Augsburger Verkehrsverbund*	46M	24
bodo	*Bodensee-Oberschwaben Verkehrsverbund*	40M	22
DING	*Donau-Iller-Nahverkehrsverbund*	<61M	34
LAVV	*Landshuter Verkehrsverbund*		9
MVV	*Münchner Verkehrs- und Tarifverbund*	449M	53
RVV	*Regensburger Verkehrsverbund*		35
VGN	*Verkehrsverbund Großraum Nürnberg*	252M	135
VVM	*Verkehrsunternehmens-Verbund Mainfranken*	54M	25
VVM	*Verkehrsverbund Mittelschwaben*	8M	10

*These numbers are based on different sources found in the text below and in Appendix A.2. For empty values no figures were published in the last years.

These are marked by additional stripes from the bottom left to the top right. In and around Munich, Nuremberg, Augsburg and in the area next to Lake Constance are even multiple payment platforms available. In contrast, for Landshut and Würzburg neither the associations nor other intermediaries provide an app for mobile ticketing.

Table 2.3 and Figure 2.5 show along the comparison of *Münchner Verkehrs- und Tarifverbund (MVV)* and *Verkehrsverbund Großraum Nürnberg (VGN)* that the number of annual rides and the number of transport firms together with the geographical size of an association are not linearly related. That is reasonable since transport firms differ in fleet and company size and geographical extend alone lacks information on population density and economic activity.

In areas where transport unions operate mobile payment is less frequent. Figure 2.5 highlights the unions with mobile payment by ragged lines. The remaining parts, however, are connected to Bavaria's central data center. Therefore, routing is feasible both online and through *Bayern-Fahrplan* or DB *Wohin Du Willst* app.

All transport regions in Bavaria are discussed in greater detail in Appendix A.2. There, the focus of the assessment lies on their regional extend and their digital portfolio.

2.2.3 Berlin & Brandenburg

Shortly after the demise of the German Democratic Republic and the German reunification, East and West Berlin's public transport providers were reunited, too. In 1994 transport planners from Berlin and Brandenburg initiated the *Verkehrsverbund Berlin-Brandenburg (VBB)*, which started operations in late 1996. Over the ensuing years *VBB* expanded until in 2005 the association covered both Berlin and Brandenburg as a whole, providing a single tariff.[57]

A first encounter with mobile services started in 1999 when an electronic ticketing system piloted on two subway lines and two bus routes in Berlin's city center. Unfortunately, this attempt struggled with user acceptance and petered out. A similar approach was later pursued by *DB* with its *Touch&Travel*-system.[58]

To enhance traveller information, a service for schedules on mobile phones was launched in 2003. This service was based on the *Wireless Application Protocol (WAP)*, which was soon outpaced by newer technologies. Thus, the provision of schedules ended shortly after the widespread emergence of smartphones in 2008.[59] With travellers carrying smartphones, more effort was put into the development of applications. Since January 2014 app-based mobile ticketing is available.[60]

Today, there are multiple applications supported by *VBB*. These differ in scope and are designed to cater different user groups. A selection is given in Table 2.4:[61] With *Jelbi* and *Moovel*, travellers can choose among two MaaS providers support-

[57] The very first single tariff for all means of transport was issued 1927 — in Berlin. See Jurziczek v. Lisone (2010) and VBB (2017).

[58] See Interessengemeinschaft Eisenbahn, Nahverkehr und Fahrgastbelange Berlin e.V. (IGEB) (1999) and IGEB (2007). For more on *Touch&Travel* cf. Appendix B.3.

[59] See VBB (2017) and IGEB (2008, p. 15).

[60] *VBB-Handyticket* and the *Berliner Verkehrsbetriebe (BVG)-app* are the services that offer mobile ticketing. See IGEB (2014) and VBB (2017). Note, in 2002 there was a small scale field test by *BVG* and former German telecommunications provider *E-Plus* where it was possible to purchase a ticket by sending a text message to the provider. See Schmitz and Strieder (2002).

[61] See VBB (2020).

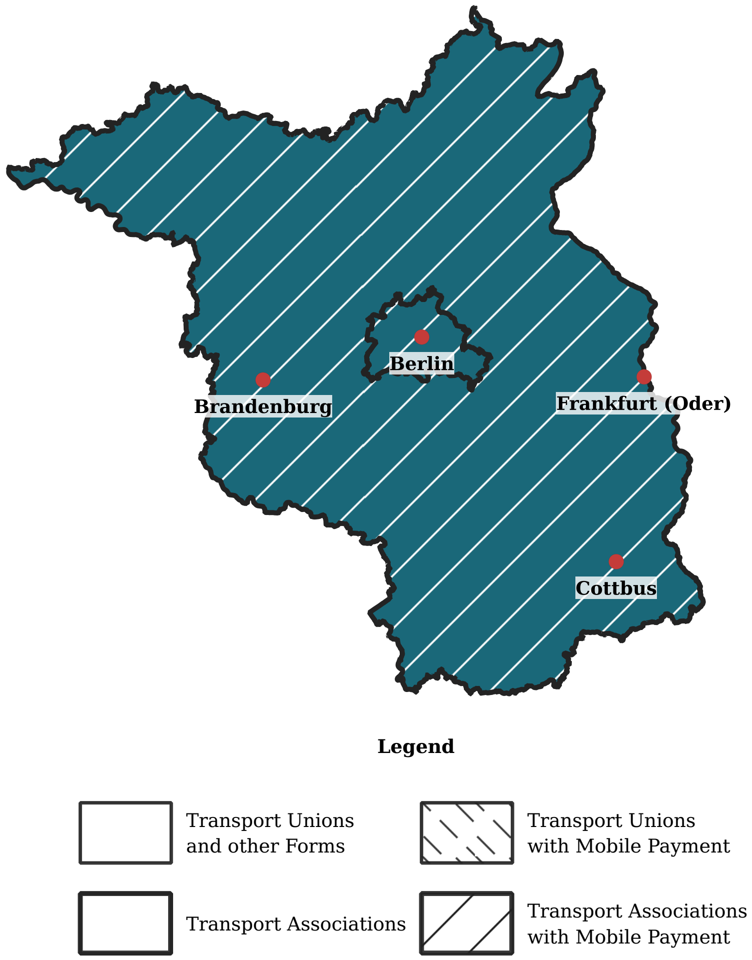

Figure 2.6: Transport intermediaries and mobile payment solutions in Berlin and Brandenburg

Table 2.4: Mobile ticketing apps in Berlin and Brandenburg

	VBB Bus & Bahn	*BVG-Apps*	*DB Navigator*	*Jelbi*	(*Moovel*)
Official app	✓	✓	✓	✓	(✗)
Berlin	✓	✓	✓	✓	(✓)
Brandenburg	✓	✗	✓	✗	(✓)
Other areas	✗	✗	✓	✗	(✓)
Single tickets	✓	✓	✓	✓	(✓)
Groups tickets	✓	✓	✓	✓	(✗)
Subscriptions	✓	✓	✓	✓	(✗)

ing more than twelve alternative private transport firms (that are not publicly tendered).[62]

To sum up, Berlin and Brandenburg provide a large set of options for mobile ticketing. With *Jelbi BVG* transitions form a second generation transport association to the third generation of a mobility alliance where transport services beyond public transport are mediated and marketed.[63]

2.2.4 Bremen

For the discussion of public transport intermediation in Bremen confer to Chapter 2.2.7 on Lower Saxony.

2.2.5 Hamburg

The Hanseatic City of Hamburg manifests the origin of transport associations. Due to the foresight of Max Morß, former head of *Hamburger Hochbahn AG (HHA)*, a local light rail service, the three main public transport providers in Hamburg initiated the *HVV* in 1965 mainly to reduce cost and expected losses.[64] Above, they aimed to loosen the frictions occurring to travellers as it was described in Chapter 2.1.1. The three partners started to cooperate and coordinate their services by

[62] And note that since the merger between *BMW*'s and *Daimler*'s mobility services the *Moovel* application is no longer available and its successor (*ReachNow*) does not support ticketing in Berlin.

[63] Cf. Figure 2.3 above.

[64] See Krause (2009, pp.28–31).

themselves. In line with Figure 2.3, the association represented the pristine form of a company alliance. Over the years *HVV* and the associated transport firms struggled to recoup their expenses. At the time when income only sufficed to cover roughly 55% of costs, *HVV* was restructured and transformed into an association lead by the government. Thereby, an authority alliance was established.[65] Subsequently, *HVV* expanded geographically towards its neighbouring states (Lower Saxony and Schleswig-Holstein). Today, *HVV* covers the city of Hamburg, the districts of Herzogtum Lauenburg, Pinneberg, Segeberg, Storman (all Schleswig-Holstein), Harburg, Lüneburg and Stade (all Lower Saxony). Within these regions the 25 associated transport firms carry more than 780 million passengers per year.

Beyond public transport, Hamburg offers a variety of alternatives. These include common transport modes, such as car sharing and rental bikes as well as on-demand services and shared taxis, e.g. *Volkswagen*'s *MOIA* service. These additional services can be booked through dedicated apps. However, *HVV* offers a distinguished app for MaaS next to their public transport *hvv App*. This app is advertised under *hvv switch* and includes the same discounts on public transport as the *standard* app, but includes the services of *MOIA*, *SIXT share*, *MILES* and *TIER*.[66]

The empirical view on Hamburg's personal transport system shows that the association makes a transition towards a mobility alliance opening its digital services to transport firms beyond public tendering. At the same time, the analysis shows that mobile ticketing and information represent established services to all involved parties.

2.2.6 Hesse

In Hesse three transport associations are responsible for public transport. These are listed in Table 2.5. Figure 2.7 illustrates the division of these within the state. In northern Hesse *Nordhessischer Verkehrsverbund (NVV)* operates, the district Bergstraße is aligned to *VRN* that links public transport across state borders to

[65] See Krause (2009, 34–41).

[66] *MOIA* is a shared taxi services. *SIXT share* and *MILES* are car sharing services. *TIER* offers e-scooters.

Table 2.5: Transport associations in Hesse

Transport association		Passengers per year*	Transport firms*
NVV	*Nordhessischer Verkehrsverbund*		35
RMV	*Rhein-Main-Verkehrsverbund*	808M	160
VRN	*Verkehrsverbund Rhein-Neckar*	310M	58

*These numbers are based on different sources found in the text below and in Appendix A.3. For empty values no figures were published in the last years.

Baden-Württemberg and Rhineland-Palatinate and the remaining larger part of Hesse is covered by *Rhein-Main-Verkehrsverbund (RMV)*. Therefore, the whole state is serviced by transport associations that offer mobile ticketing. The three transport associations have formulated aims for the coming years. These include a) a simple pricing structures within their purview that allow interchanges to neighbouring tariffs, b) electronic tickets and c) in the long-run state-wide tariffs. Above these aims, Hesse's public transport law demands intermodal transport possibilities that explicitly go beyond public transport alone.[67]

RMVsmart marks an example for the digital innovations the associations promote. This pilot is designed to test multiple new sales features. Most notably, the new tariffs depend on app-usage and allow either discounts based on the monthly revenue generated or a two-part tariff based on a fixed fee and a 50% discount on all single rides. Both options can be expanded to test a be-in/be-out system. Therefore, consumers need to give extended rights to the app, such as Global Positioning System (GPS) and *Bluetooth*. Then, the phone recognises a passenger entering or leaving a vehicle. For the passenger this improves comfort as he does not need to manually check-in or -out. The innovative sales experiment may offer an outlook on how transport intermediation will look like in the future without a free market for intermediation.[68]

[67]See §4 subsection 3 and 5 Gesetz über den öffentlichen Personennahverkehr in Hessen (HÖPNVG).
[68]Additional information on the services offered in Hesse are described in Appendix A.3.

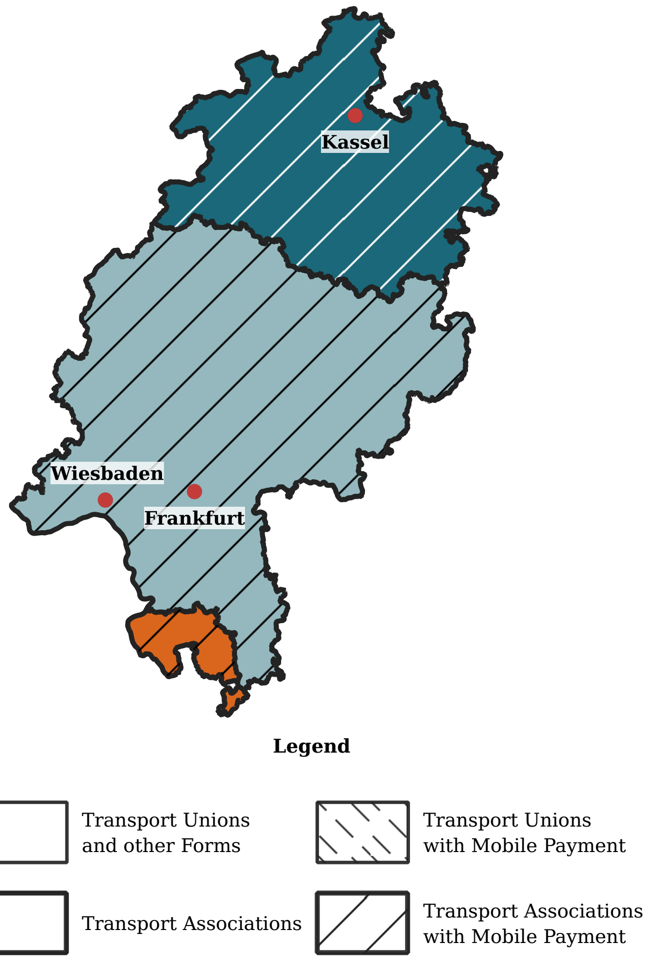

Figure 2.7: Transport intermediaries and mobile payment solutions in Hesse

Table 2.6: Transport associations in Lower Saxony

Transport association		Passengers per year*	Transport firms*
GVH	*Großraum-Verkehr Hannover*	219M	6
HVV	*Hamburger Verkehrsverbund*	785M	25
ROSA	*ROSA Hildesheim*		3
VBN	*Verkehrsverbund Bremen/Niedersachsen*	175M	32
VEJ	*Verkehrsverbund Ems-Jade*	30M	15
VRB	*Verkehrsverbund Region Braunschweig*	100M	22
VSN	*Verkehrsverbund Süd-Niedersachen*	36M	16

*These numbers are based on different sources found in the text below and in Appendix A.4. For empty values no figures were published in the last years.

2.2.7 Lower Saxony

As in other states, public transport in Lower Saxony is divided into railway services and other modes. Railways are (mostly) centrally administered by the state government while local public transport is managed on different levels. These go from single municipalities up to transport associations in regions comprised of several administrative districts. However, ultimate authority on public transport lies in the scope of districts and urban municipalities.

Taking the heterogeneity in population density withing Lower Saxony and looking on the map of public transport services in Figure 2.8, a connection between the size and status of the transport intermediary can be seen. Specifically, in larger conurbations including Bremen public transport is governed by a transport association while in rural areas, such as the western parts of Lower Saxony, tariff associations and transport unions prevail.[69]

In detail, there are currently 18 transport intermediaries in Lower Saxony and Bremen.[70] Of these, seven are organised as transport associations and highlighted by bold edges and dark colours. Table 2.6 list these along data on passengers and associated transport firms.

[69] See Reinhardt (2018, p. 148) and Niedersächsisches Nahverkehrsgesetz § 4.

[70] Note that on the East Frisian Island public transport is organised individually together with the ferries. Cf. Appendix A.4. Furthermore, the brown-coloured area in the north-east in Figure 2.8 is connected to the transport union of Ludwigslust-Parchim. This corresponds to the municipality of Amt Neuhaus. Cf. Appendix A.5.

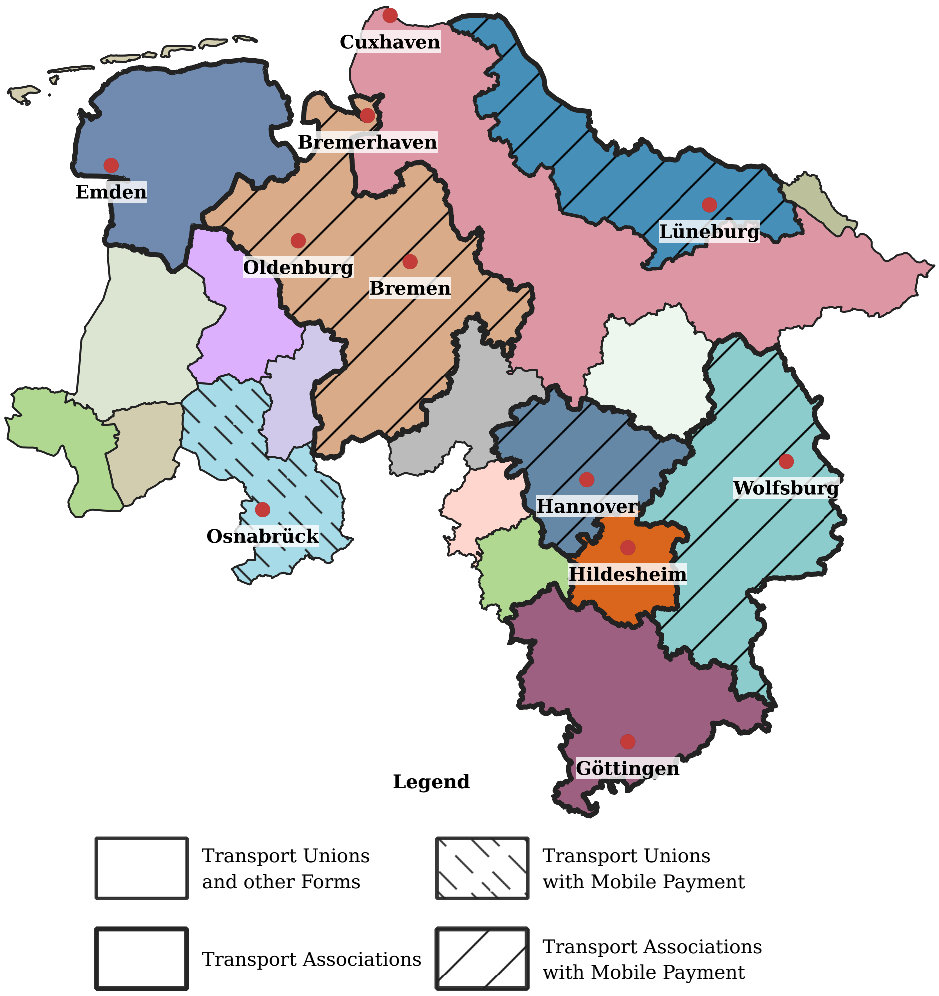

Figure 2.8: Transport intermediaries and mobile payment solutions in Lower Saxony

As Figure 2.8 indicates by the hatched areas, only *GVH*, *HVV*, *VBN*, *VRB* and the transport union *Verkehrsgemeinschaft Osnabrück (VOS)* offer mobile ticketing. Generally, digital information is wide spread in the more densely populated ares of Lower Saxony. In contrast, the fragmented rural regions, mainly next to the Dutch border, operate public transport in less structured forms. This partly explains, why mobile ticketing is less common in these areas. A detailed review of all transport regions in Lower Saxony is given in Appendix A.4

2.2.8 Mecklenburg-Vorpommern

In the state of Mecklenburg-Vorpommern there operates currently only *Verkehrsverbund-Warnow (VVW)* as a transport association. It was founded in 1997 by the local transport suppliers and since 1998 there are coordinated tariffs and schedules. Subsequently, the association grew, both with regard to the number of transport firms[71] and to the geographical extend.

The association initiated mobile ticketing in 2018. Together with its partner *HaCon Ingenieurgesellschaft mbH* they offer the *VVW*-App. Besides information on routing and live data (by some transport suppliers) ticketing for single rides or daily tickets is available.[72] Since late 2019, 62 million annual passengers can buy mobile tickets though *DB Navigator*, as well.

In 2016 the two bus companies *Grevesmühlener Busbetriebe GmbH* and *Eigenbetrieb Nahverkehr Nordwestmecklenburg* merged and founded *NAHBUS Nordwestmecklenburg*. It covers the area of the eponymous district. The union offered online tickets on their website, however, the service has been stopped recently.

In Schwerin *Nahverkehr Schwerin GmbH (NVS)* operates public transport. It is a vertically integrated firm covering all aspects of transport itself. Since September 2019 mobile ticketing is available through their app offering a limited scope of tickets. However, the app is designed for ticketing only, referring passengers to other sources to plan their trip and getting information on schedules. This means,

[71]Today, six transport firms are affiliated with *VVW*.
[72]See VVW (2018).

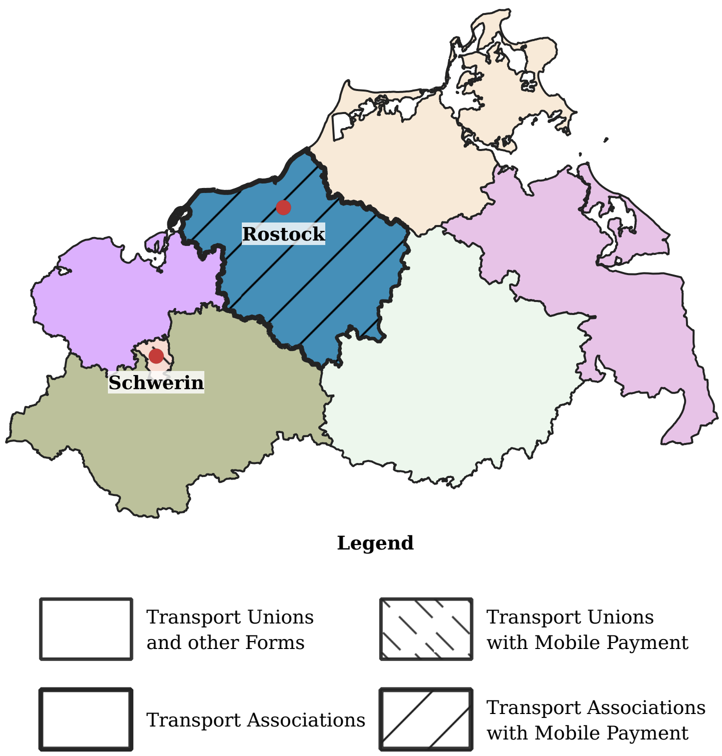

Figure 2.9: Transport intermediaries and mobile payment solutions in Mecklenburg-Vorpommern

another app, a physical timetable or map are required to obtain information on routing.

In the remaining parts of Mecklenburg-Vorpommern public transport is less centralised. Appendix A.5 adumbrates these other areas that are organised by either transport unions (in northern and western Mecklenburg-Vorpommern) or by local firms.

Railway services in Mecklenburg-Vorpommern are, similarly to other German states, administered by state government and offer independent tariffs (except in *VVW*). With the integrated transport plan 2018, the state strives for more transparent and accessible information of travellers. Focus of this campaign lies on intermodal traffic, including explicitly information on car-sharing.[73]

Today, an app[74] exists that supplies timetables for both bus- and rail-systems across the entire state. As a statewide tariff failed in 2011, there are currently no ambitions to integrate ticketing into this app.[75]

To sum up the status of digitalisation of public transport in Mecklenburg-Vorpommern, there is only one transport association offering mobile ticketing and live data (*VVW*). This is shown by the saturated blue area in Figure 2.9. Furthermore, the map shows that the transport union in Schwerin offers mobile ticketing while the remaining parts of the state does not. For these regions, however, timetables are accessible online.

2.2.9 North Rhine-Westphalia

Over the years public transport in North Rhine-Westphalia (NRW) was reorganised several times. These changes can be classified by three periods:

In the first, public transport was organised by transport firms themselves. Three transport associations were founded in the highly populated areas[76] and around

[73]See Ministerium für Energie, Infrastruktur und Digitalisierung Mecklenburg-Vorpommern (2018, pp. 84–85).

[74]The app is branded *MV FÄHRT GUT* and it piloted in 2015. See Ministerium für Energie, Infrastruktur und Digitalisierung Mecklenburg-Vorpommern (2018, p.72–73).

[75]See Ministerium für Energie, Infrastruktur und Digitalisierung Mecklenburg-Vorpommern (2018, p. 85).

[76]These are *Aachener Verkehrsverbund (AVV)*, VRR and *Verkehrsverbund Rhein-Sieg (VRS)*.

Table 2.7: Transport associations in North Rhine-Westphalia

Transport association		Passengers per year	Transport firms
AVV	*Aachener Verkehrsverbund*	18M	8
NWL	*Zweckverband Nahverkehr Westfalen-Lippe*	375M	60
VRR	*Verkehrsverbund Rhein-Ruhr*	1.14B	35
VRS	*Verkehrsverbund Rhein-Sieg*	555M	19

other conurbations the transport firms agreed on tariffs and established transport unions. According to the classification in Figure 2.3 above, these were company alliances. At the same time, regional rail transport was organised on state level, such that the systems provided by the transport associations and unions were separated.[77]

With many different tariffs, state government took action in form of the RegG in 1996 and NRW's public transport law.[78] Thereby, local government entered the transport associations, which changed their legal form. This marks the beginning of the second period. Furthermore, NRW was divided into nine regions. In each region, cooperation between existing parties was accelerated by launching associations above the existing transport organisations. By this step, the tariffs were adjusted to include regional train transport. These developments marked the second stage in NRW's public transport organisation.[79]

The last period started with the amendment of the ÖPNVG NRW in 2007.[80] By 2009, the nine regions were consolidated into three areas with only three superordinate associations. These are *Zweckverband Nahverkehr Rheinland (NVR)* in the south, *NWL* in major parts of Westphalia[81] and *VRR* in the north-western parts of NRW.

[77]See VRS (2020).
[78]In German: Gesetz über den öffentlichen Personennahverkehr in Nordrhein-Westfalen (ÖPNVG NRW).
[79]See VRS (2020).
[80]Note that the associations remain authority alliances in the sense of Figure 2.3.
[81]Including Lippe.

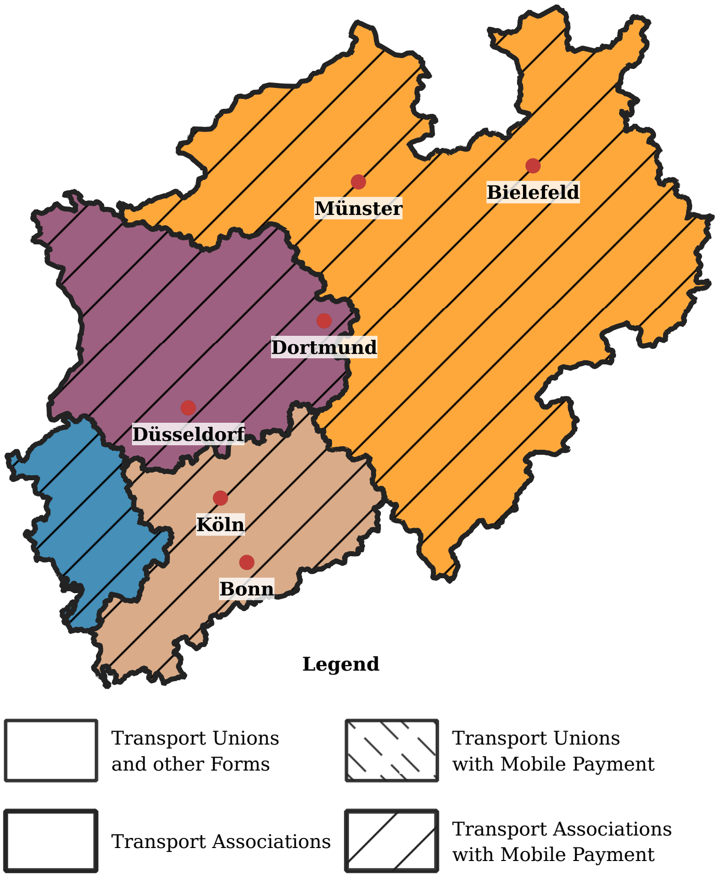

Figure 2.10: Transport intermediaries and mobile payment solutions in North Rhine-Westphalia

Except for *NVR*, the regions offer a single tariff for all public transport services.[82] For *AVV* and *VRS*, the two associations that comprise *NVR*, separate tariffs are available, but special tickets ensure validity for both transport associations. NRW's transport associations are listed in Table 2.7 and mapped in Figure 2.10. In addition, there is a statewide tariff (*NRW-Tarif*) that is accepted on all rides.[83]

Contrary to other German federal states, there exists a plethora of applications in NRW. For *AVV*, tickets can be purchased via *Handyticket Deutschland* since 2011 and since 2019 through *DB Navigator*. *AVV*'s proprietary app, *AVV connect*, offers only routing and information to the transport services by the nine affiliated firms.

In *VRS Handyticket Deutschland* has been superseded by *VRS Auskunft*. It offers discounts on tickets in comparison to those bought through other channels. Beyond that, both car sharing and rental bikes can be booked through the app.[84]

For the remaining parts of NRW, the associated transport firms have the possibility to sell tickets online by themselves. To do this, there is an Application Programming Interface (API) that these firms can access. Consequently, many transport firms offer their own app to their customers. For *NWL* and *VRR* Table 2.8 list the available apps.

Furthermore, a state wide tariff using a check-in/check-out system has been established in 2021. In the preceding years the system was known under the pilot *etarif* while today it is branded *eezy*. It offers a two-part tariff on each ride consisting of a fixed fee and a distance-depended variable share. The system uses GPS data at departure. When passengers log-off, only the distance according to beeline is charged.

To conclude the analysis on NRW, a broad spectrum of mobile ticketing alternatives for public transport is offered. However, public transport is administered by second generation associations. Only *VRS* offers payment solutions that include

[82] *Westfalentarif* and *VRR-Tarif* in *NWL* and *VRR*, respectively.
[83] See VRS (2020).
[84] As car sharing providers *cambio* and *wupsiCar* are supported. For rental bikes there are *KVB-rad*, *SWBmobil*, *wupsiRad*, *RVK-Rad* and *RSVG-Rad*. Note that the last two are in cooperation with *Nextbike* and can also be booked through their proprietary app.

Table 2.8: Ticketing apps in NWL and VRR

NWL	VRR
WestfalenTarif-App	*VRR-App*
Handyticket Deutschland	*Handyticket Deutschland*
DB Navigator	*DB Navigator*
BuBiM-App	*Mutti-App*
fahrtwind-App	*HST-app*
mobil info-App	*myDVG-App*
Veelker App	*Rheinbahn Fahrplanauskunft-App*
MVG Tickets-App	*ZÄPP Die Ruhrbahn App*
eurobahn Tickets-App	*SR App*
OWLmobil-App	*STOAG-App*
münster:app	*neuss mobil-App*
DB NRWay-App	*Vestische App*
fahr mit-App	

Table 2.9: Transport associations in Rhineland-Palatinate

Transport association		Passengers per year*	Transport firms*
VRM	*Verkehrsverbund Rhein-Mosel*	114M	41
VRT	*Verkehrsverbund Region Trier*	21M	24
RNN	*Rhein-Nahe Verkehrsverbund*		14
VRN	*Verkehrsverbund Rhein-Neckar*	310M	58
KVV	*Karlsruher Verkehrsverbund*	166M	33

*These numbers are based on different sources found in the text below and in Appendix A.1 and A.6. For empty values no figures were published in the last years.

non-publicly tendered transport services. Therefore, *VRS Auskunft* is the sole MaaS provider in NRW.

2.2.10 Rhineland-Palatinate

Public transport in Rhineland-Palatinate is administered by five transport associations as shown in Figure 2.11. Railway services are contracted on a level above the transport associations by two special purpose associations. However, schedules and integration of regional rail transport is conducted by the transport associations.

The five associations all offer mobile payment options. In Table 2.9 these associations are listed along the number of rides performed per year as well as the number

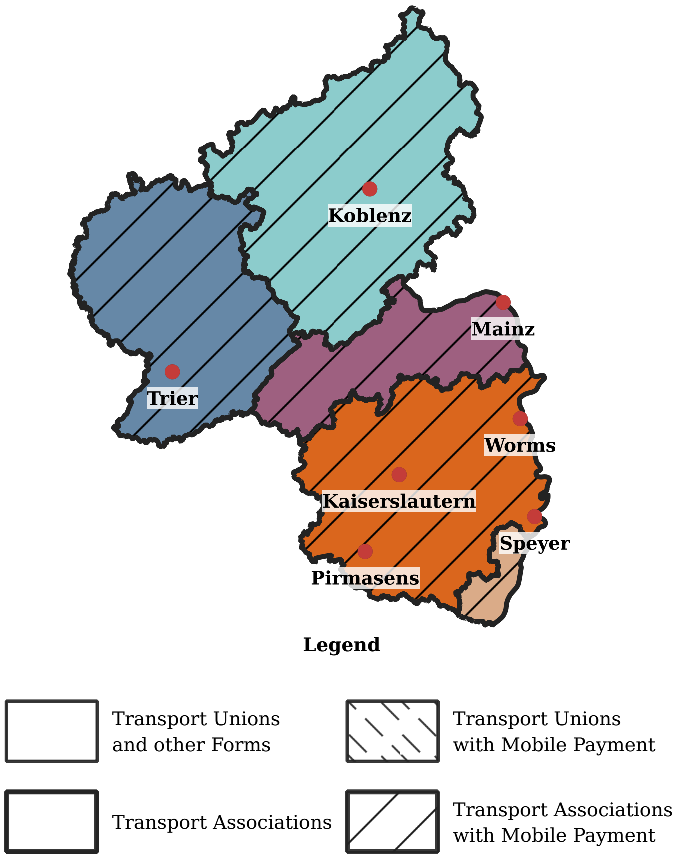

Figure 2.11: Transport intermediaries and mobile payment solutions in Rhineland-Palatinate

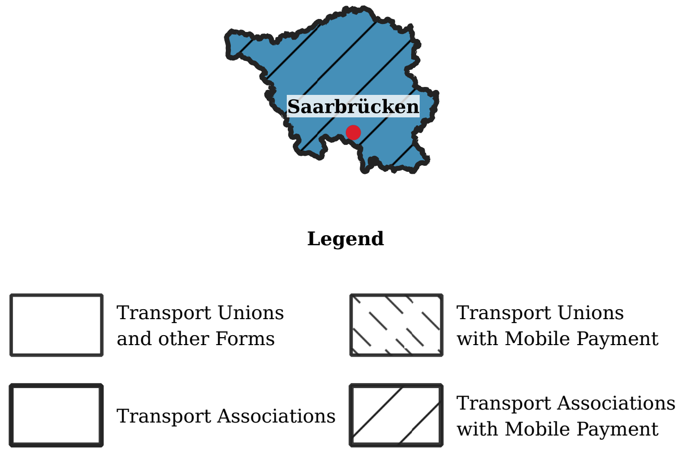

Figure 2.12: Transport intermediaries and mobile payment solutions in Saarland

of transport firms that operate within these. *VRN* and *KVV* are both associations that operate beyond the borders of Rhineland-Palatinate. They give an example on how the markets for mobility are less determined by legal borders, rather than by actual traffic flows. More details on the five associations is given in Appendix A.1 and A.6.

The line services provided by transport associations are amended by currently 81 *Bürgerbusse*. These represent a kind of voluntary public transport in small scale adjusted to local needs where the services of the associations are insufficient.[85]

2.2.11 Saarland

In 2005 the state Saarland founded the *Saarländische Verkehrsverbund (SaarVV)* as a transport association. It comprises the whole state as it is shown in Figure 2.12.[86] 15 transport firms offer their services through the association. In 2019 the transport association published its mobile app *Saarfahrplan*. Unfortunately, the app is limited to the offerings of public transport excluding car-sharing and other private ventures, such as electric scooters.

[85] See Agentur Landmobil (2021).
[86] See Knieps (2009, pp. 21–22).

Table 2.10: Transport associations in Saxony

Transport association		Passengers per year*	Transport firms*
MDV	*Mitteldeutsche Verkehrsverbund*	228M	20
VMS	*Verkehrsverbund Mittelsachsen*	80M	26
VVO	*Verkehrsverbund Oberelbe*	219M	12
VVV	*Verkehrsverbund Vogtland*		4
ZVON	*Zweckverband Verkehrsverbund Oberlausitz-Niederschlesien*		10

*These numbers are based on different sources found in the text below and in Appendix A.7. For empty values no figures were published in the last years.

The local ministry of transport is about to renew its development plan for public transport (*Verkehrsentwicklungsplan Öffentlicher Personennahverkehr/public transport (ÖPNV)*).[87] The focus of the plan will lie on bus and rail tenders while presumably other firms of mobility will be discussed, too.

2.2.12 Saxony

In Saxony public transport was restructured in 1995 by the public transport law of Saxony.[88] According to § 2 (5) ÖPNVG, the districts and cities established so-called *Zweckverbünde* to organise public transport. These administrative unions led to the five public transport associations in Saxony. Table 2.10 lists these along key figures on passengers and transport firms. To illustrate these, Figure 2.13 depicts the associations on a map. Mobile ticketing is supported on state level since the beginning of the noughties. More details on Saxony's transport regions and their digital agenda are given in Appendix A.7.

2.2.13 Saxony-Anhalt

Figure 2.14 illustrates the public transport structure in Saxony-Anhalt where two transport associations are highlighted. Both are listed in Table 2.11, which describes these with regard their size in terms of annual rides and the number of transport

[87]See Ministerium für Wirtschaft, Arbeit, Energie und Verkehr des Saarlandes (2020).
[88]In German: Gesetz über den öffentlichen Personennahverkehr im Freistaat Sachsen (ÖPNVG)

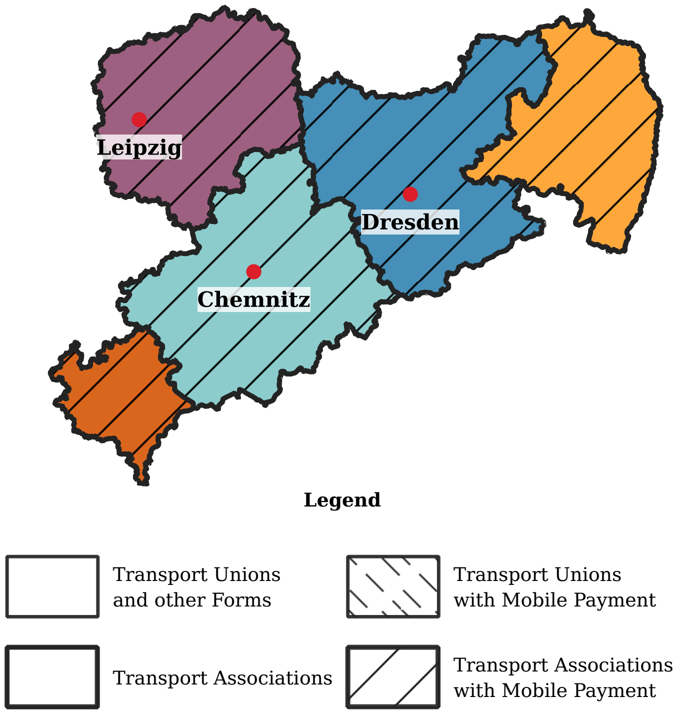

Figure 2.13: Transport intermediaries and mobile payment solutions in Saxony

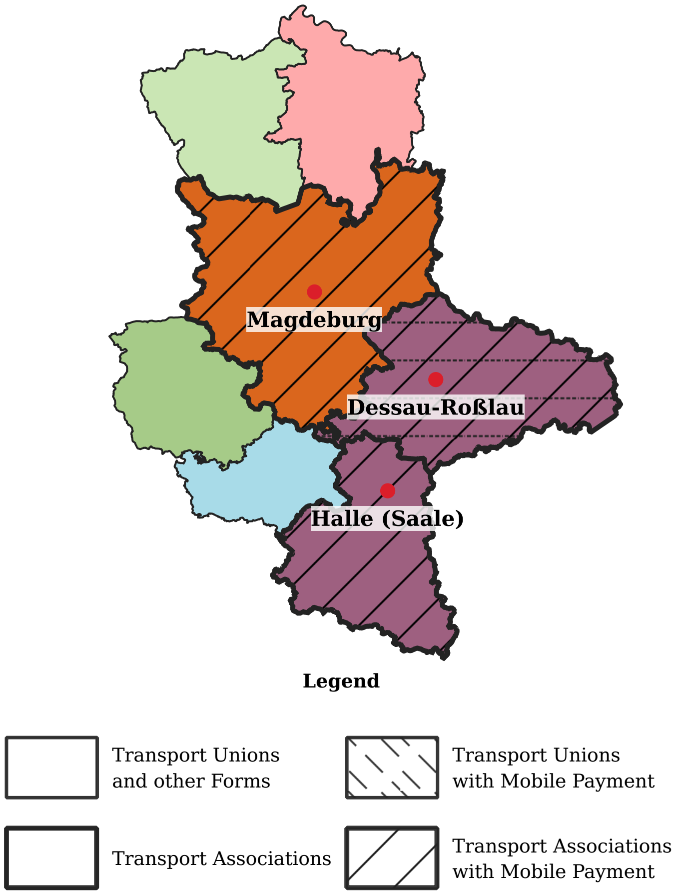

Figure 2.14: Transport intermediaries and mobile payment solutions in Saxony-Anhalt

Table 2.11: Transport associations in Saxony-Anhalt

Transport association		Passengers per year*	Transport firms*
marego	*Magdeburger Regionalverkehrsverbund*		8
MDV	*Mitteldeutsche Verkehrsverbund*	228M	20

*These numbers are based on different sources found in the text below and in Appendix A.8. For empty values no figures were published in the last years.

firms operate the services. For both associations, passengers can purchase tickets by a selection of apps.

In the northern and western parts of the state, public transport is managed by transport firms and unions. Consequently, they lack dedicated apps and passengers do not have the possibility to purchase mobile tickets. Summing up, roughly half of Saxony-Anhalt is covered by transport associations offering mobile ticketing. In the remaining parts passengers can obtain information through *INSA* as a mobile tool. The service announced to offer ticket sales the near future. Thereby, mobile ticketing will become possible for all public transport services within the state. Appendix A.8 offers more insights on the status quo of public transport in Saxony-Anhalt.

2.2.14 Schleswig-Holstein

In Schleswig-Holstein local government consolidated public transport in 2014. The new transport association originated from the 1995 founded *Landesweite Verkehrs-servicegesellschaft (LVS)*, which was primarily responsible for railroad services. In contrast to the old service level, the new *Nahverkehrsverbund Schleswig-Holstein (NAH.SH)* administers both railway services and road-based public transport. To provide the transport services *NAH.SH* partners with 36 transport firms. Together, these firms transport approximately 62 million passengers each year in the name of the association. Geographically, the association's tariffs cover the whole state with a few exceptions, such as bus transport on Sylt and other North Frisian Islands as well as rides within the administrative district of Schleswig-Flensburg. On the

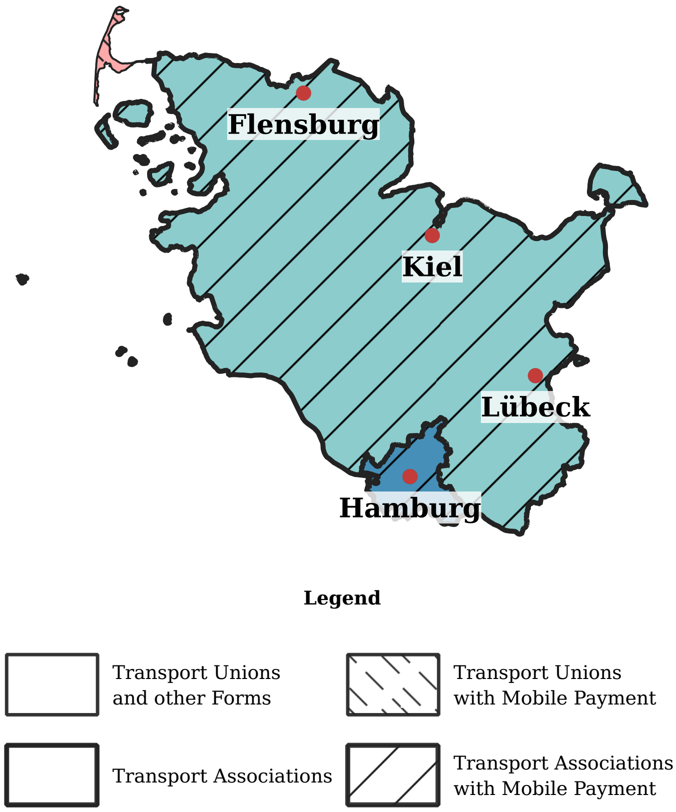

Figure 2.15: Transport intermediaries and mobile payment solutions in Schleswig-Holstein

other side, tickets from and to Hamburg (*HVV*-area) can be purchased using the *Schleswig-Holstein-Tarif (SH-Tarif)*. Furthermore, there are ticketing-partnerships on some routes to Denmark and Mecklenburg-Vorpommern. Thus, the personal transport landscape is divided in roughly three parts as Figure 2.15 illustrates.[89]

In 2008 the first mobile ticketing system was available for the connection between Hamburg and Sylt. The system lacked adoption by travellers and was shut down in 2011. Lübeck became in 2009 one of the pilot cities of *HandyTicket Deutschland*. Due to financial restraints and unfulfilled expectations the program ended the same year. Furthermore, there was a trial with 50 travellers testing *Touch&Travel* in

[89]See NAH.SH (2020a), NAH.SH (2020c) and Landesweite Verkehrsservicegesellschaft Schleswig Holstein (2014, pp. 87–89).

2009 between Kiel and Lübeck and within the city Eutin. Between 2012 and 2016 *Touch&Travel* could be used on Sylt.[90]

As of June 2020, the *Sylter Verkehrsgesellschaft* partnered with DB offering all kinds of tickets through *DB-Navigator*.[91] Just one month later, *NAH.SH* added a payment feature to its *NAH.SH-app*. At the same time, *SH-Tarif* became available through *DB-Navigator*. Both apps now offer a reduced set of tickets including one-way tickets and daily tickets. Therefore, travellers can purchase *all* tickets for public transport in Schleswig-Holstein online.[92]

2.2.15 Thuringia

In Thuringia public transport is organised on different levels of government: For (short distance) rail traffic the state government has closed contracts with *DB Regio AG*, *Harz Narrow Gauge Railways (Harzer Schmalspurbahnen GmbH)*, *Süd-Thüringen-Bahn GmbH* and *Erfurter Bahn GmbH*.[93]

Beyond these rail services, there are currently two transport associations in Thuringia. These services are mandated by local government. One is *Mitteldeutsche Verkehrsverbund (MDV)*[94] in the administrative district Altenburger Land at the very east of Thuringia. *Verkehrsverbund Mittelthüringen (VMT)* represents the other. It currently covers the districts of Gotha, Erfurt, Gera, Jena, Saalfeld-Rudolstadt, Saale-Holzland-Kreis, Saale-Orla-Kreis, Weimar and Weimarer Land. In Figure 2.16 these association are highlighted by opaque and strong colours and bold contour lines in the center and to the very right of the graph.

According to the Thüringer Ministerium für Infrastruktur und Landwirtschaft (2018, pp. 95–97) Thuringia's government seeks to establish a statewide transport

[90] See Landesweite Verkehrsservicegesellschaft Schleswig Holstein (2014, p. 88), Wagner and Engelen (no date, pp. 15–30) and Bahnaktuell (2009).

[91] See Hasse (2020).

[92] See NAH.SH (2020b) and NAH.SH (2020d, pp. 80-81).

[93] See Thüringer Ministerium für Bau, Landesentwicklung und Verkehr (2014, pp. 31–33) and Thüringer Ministerium für Infrastruktur und Landwirtschaft (2018, p. 25). There are also contracts with cross-border transport providers to Saxony and Hesse. These are *Abellio Rail Mitteldeutschland GmbH* and *Cantus Verkehrsgesellschaft mbH*, cf. Thüringer Ministerium für Infrastruktur und Landwirtschaft (2018, pp. 41–42).

[94] Cf. Chapter A.7 below.

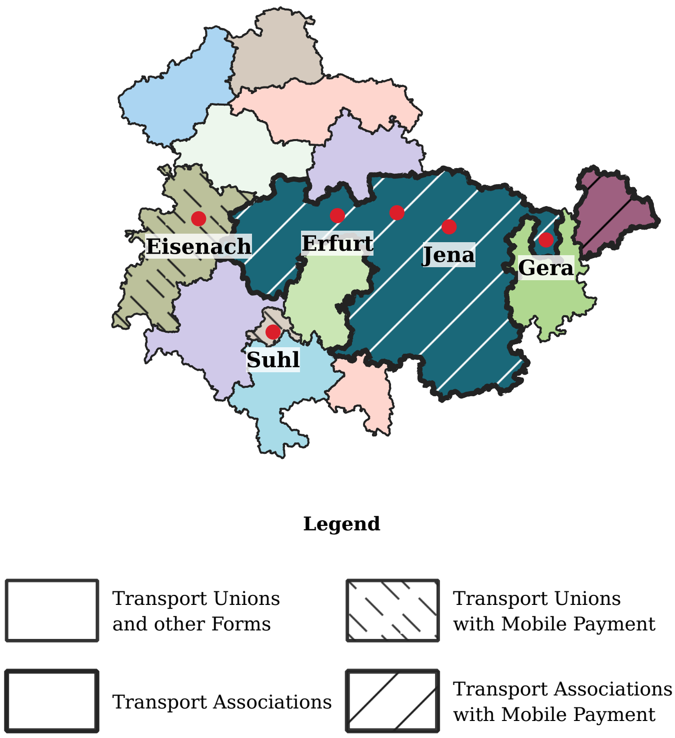

Figure 2.16: Transport intermediaries and mobile payment solutions in Thuringia

association emerging from *VMT*. The plan comprises in a first stage all administrative districts within Thuringia except Eichsfeld, Kyffhäuserkreis, Nordhausen and Unstrut-Hainich-Kreis (all Northern Thuringia), Greiz (which is a member of *ErgoNet*-association) and Alternburger Land which is affiliated to *MDV*. In the same step, Thuringia plans to improve and standardise its digital infrastructure with respect to tariff data, traveller information and general interfaces. The reason behind this are to serve travellers' needs, but also to comply with European law as passed by the The European Commission (2017) in the *Commission delegated regulation (EU) 2017/1926 of 31 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services.*[95]

All further public transport offerings are organised by the local districts. In Figure 2.16 these are marked by the pale coloured areas. As the size of these districts and the number of public transport users are small, only a few provide mobile payment or dedicated apps. Among these are the two transport associations[96], public transport in Eisenach, Wartburgkreis and in Suhl/Zella-Mehlis. For Eisenach and its surrounding Wartburgkreis *HandyTicket Deutschland* was introduced for the *Verkehrsgemeinschaft Wartburgregion* (a transport union founded in 2019 comprised of five bus companies) including state tendered rail services in 2020. Similarly, in Suhl and its adjacent municipality Zella-Mehlis *HandyTicket Deutschland* is available for mobile ticketing on bus routes.

The investigation of Thuringia's personal transport services has shown that the state aims at improving public transport. Today, both the two transport associations offer electronic ticketing and in the districts of Eisenach and Suhl provide mobile ticketing. In the remaining districts the tendered firms offer scattered tariffs. Since development costs or licensing apps is too costly for these smaller transport firms, no mobile payment applications are available.

[95] See (Thüringer Ministerium für Infrastruktur und Landwirtschaft, 2018, pp.86–100) and cf. Chapter 2.1.5 above.

[96] These are MDV and VMT, including *KomBus* in Saalfeld-Rudolstadt and Saale-Orla-Kreis that was integrated into VMT in 2020.

Table 2.12: Transport regions offering mobile ticketing in Thuringia

Transport region		Passengers per year*	Transport firms*
MDV	*Mitteldeutsche Verkehrsverbund*	228M	20
VMT	*Verkehrsverbund Mittelthüringen*	95M	15
	Nahverkehrsgesellschaft Suhl/Zella-Mehlis	3.5M	1
	Verkehrsgemeinschaft Wartburgregion		

*These numbers are based on different sources found in the text. For empty values no figures were published in the last years.

Table 2.13: Mobile ticketing in German public transport regions

	Mobile Channels		**Traditional Channels**	
	By regions	By population	By regions	By population
Associations	45 (37 %)	69.5 m (84 %)	9 (7 %)	2.9 m (3 %)
Unions and others	9 (7 %)	2.6 m (3 %)	58 (48 %)	8.1 m (10 %)
Σ	54 (45 %)	72.1 m (87 %)	67 (55 %)	11 m (13 %)

Population data is based on district data from the Federal Statistical Office of Germany in 2021. The data represents Germany's population at the end of 2020 and is mapped to the spatial data of the analyses.

2.2.16 Conclusion

Summing up, the analysis of the German public transport landscape showed that digitalisation in German personal transport is progressing and that in all major cities mobile information and mobile ticketing are available and established. More than 80 % of the transport associations offer mobile ticketing, amounting for almost 45 % of all transport regions as Table 2.13 shows. With regards to population, Table 2.13 displays that around 87 % have the option to purchase their tickets through mobile channels. The findings in Table 2.13 support the theory that transport associations are mainly found in densely populated areas while transport services in rural areas are less structured.

Furthermore, the analyses have shown that transport associations in Germany's largest cities even support multiple mobile apps providing (live) data on transport supply. Beyond that, some of these app support mobile ticketing. While these ticketing apps are diversified with respect to the scope of tickets provided, the proprietary apps have the largest scope including subscription tariffs. Some of these apps facilitate passengers' transactions with transport firms outside of the public transport scope. This includes taxi services, e-scooters or even car-sharing.

The market of proprietary apps by transport associations is generally limited to the area of the associations. Often there are agreements with neighbouring transport associations and unions. For these cases, the apps also include both information and tickets for rides to and from these regions.

The analysis[97] has indicated that there are transport intermediaries which operate on a different level. Among these are *DB Navigator* and *Verband Deutscher Verkehrsunternehmen (VDV)*'s *HandyTicket Deutschland*, who offer their services in multiple transport regions or even for intercity connections. With these apps, only a subset of tickets can be purchased and other modes than public transport are not or only to a smaller extend supported. These differences to regional public transport apps are shown in Figure 2.17. While proprietary apps are geared to the needs of urban public transport, these panregional apps are differentiated with regard to their core capabilities. To stick to the example above, *DB Navigator* caters primarily to passengers travelling by rail while *HandyTicket Deutschland* is all about conducting payments for urban rides.

With respect to competition among intermediaries for all transport services, there are often only a few or even just a single option to purchase tickets online or on a mobile device. A diverging example are the apps in North-Rhine Westphalia where the ticketing interface is licensed to more than ten app developers. This motivates the model-based analyses that help to understand existing market configurations. Furthermore, by facilitated models, the incentives platforms have with respect to both users and transport firms can be identified. This means, under which conditions will travellers consider an intermediary and if they can choose

[97]In conjunction with the discussions in both Appendix A and B.

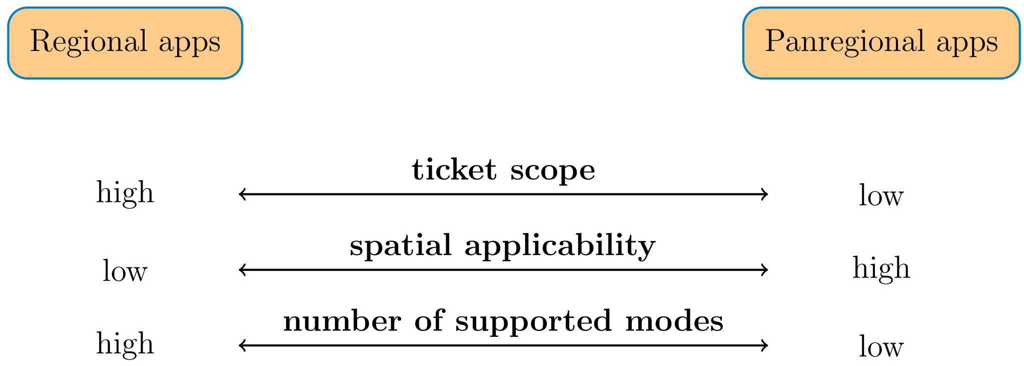

Figure 2.17: Regional apps vs. panregional apps

between multiple, which one will they choose? The same questions will be raised to transport firms.

There are several approaches to explain non-participation with a service. Among these are general thoughts on intermediation or, to name an alternative, a quality view on non-price competition. Therefore, the literature and key findings of both approaches are reviewed in the next two chapters.

3 Theory of intermediation

As shown in the previous chapter, the personal transport landscape developed from a market with direct sales from transport firms to travellers to a market where transport associations and new forms of information guides are established. Despite fundamental differences in their aims and responsibilities, both transport associations and MaaS represent a form of market intermediation. This chapter characterises intermediaries from a theoretical point of view. The pivotal question in this discussion is, what benefits do intermediaries create and, thus, why they exist?

An additional aspect that applies to the transport market is analysed in Section 3.2. Here, some participants refrain from using an intermediary's services. Instead, the market participants can rely on known means. In the transport setting, an owned car or bicycle represents an example to refrain from (public) transport intermediation. To illustrate the matter analytically, the model by Gehrig (1993) is discussed in detail as it allows for endogenous demand for intermediation.

3.1 Reasons for intermediation

Brick and mortar stores are the traditional example of an intermediary. These stores buy goods from producers and resell them at a higher price to consumers. From this first picture revenues and incentives of an intermediary become clear. But the following question remains: why do consumers and producers take this road and do not meet directly, instead?

The answer to this question is not singular as multiple explanations come to mind. Spulber (1999, p. xiii) summarises these as "reducing transaction costs", "pooling and diversifying risk", "lowering cost of matching and searching", "alleviating adverse selection", "mitigating moral hazard and opportunism" and "supporting commitment through delegation". From a different point of view, this list can be (non-exclusively) augmented by offering immediacy, reducing asymmetric information or economies of both scale and scope. Taking a closer look at each direction, these explanations overlap or could even be integrated in one another. For example in Spulber's case, the first three reasons could be summarised under reducing transaction costs.[98]

Sticking to this point, Stigler (1961) argues that search costs are a part of transaction costs. Since consumers are unaware of the best price offered and the fact that price dispersions[99] exist, consumers need to glean offers and collect information on prices. Similarly, sellers require buyers who purchase their product. Thus, sellers want to know consumers' reservation prices, too. Consequently, the author's argument is that this process can be conducted more economically by an intermediary gathering that information only once and distributing it to the affiliated parties.[100] Thereby, the central institution reduces search costs in the first place, but at the same time diminishes costs associated with possible bargaining or haggling. Both forms of reductions are consequently enhancing an intermediary's efficiency. Reducing search costs by collecting and analysing data of market participants represents economies of scale. Applying the gained information to decrease the cost of the actual transactions gives middlemen a way to obtain a benefit in the scope of finalising sales.

[98] The risk argument does not fit in this group at the first glance, however, Diamond (1984) analyses this problem with regards to monitoring costs in (long term) loans. Indeed, Diamond's model fits into the category of alleviating transaction costs as well.

[99] Stigler (1961, p. 213) emphasises that this dispersion can be even observed "for homogeneous goods".

[100] In Stigler's model, search costs for consumers are modelled to be dependent on the number of observed sellers. As for the former, it takes time to obtain information on each seller. Therefore, the time required for this process is considered to be proportional to the number of sellers and marks the key determinant of the costs of search. See Stigler (1961, p. 216).

3.2 Endogenous intermediation

So far, the explanations for intermediation focussed on transaction costs, asymmetric information and economies of scale and scope. Above, immediacy was mentioned as an additional reason for intermediation. By that term the instant disposition for trade is meant. Harris (2003, p. 70) explains this role as providing access to networks[101] of buyers and sellers. Above, he claims that in financial markets immediacy is tantamount to providing liquidity to the market. This last idea is taken from Demsetz's 1968 seminal paper on the New York stock exchange. He compares immediacy with holding an inventory of retailers and brick and mortar stores. The costs for holding an inventory are represented by the markup retailers charge on top of their initial purchasing price. By the same argument, providing liquidity is similar to holding stock as it enables others to trade immediately. The bid-ask spread in these markets is tantamount to the costs for standing ready to buy or sell. Consequently, lower spreads indicate a more active market than higher spreads. That means, waiting time for market orders can be used to determine the spread.[102]

If specialists, who in Demsetz's article provide immediacy, choose to widen the spread to increase their profits, traders could bypass the specialist by Over-the-Counter (OTC) transactions.[103] Motivated by the idea that not all transactions take place on an intermediary's watch, Gehrig (1993) proposes a model that explains why some market participants choose to trade with an intermediary and why some do not.

Despite originally designed for the stock market, the model's interpretation can easily be adjusted to personal transport market: Here, some travellers refrain from using a transport association's information and (mobile) payment infrastructure.[104]

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[101] Cf. Chapter 4.3.

[102] See Demsetz (1968, pp. 35–50).

[103] Of course, there are other constraints that force specialists to maintain an appropriate spread. Demsetz (1968, pp. 43–45) names competition from other specialists, submission of limit orders that are exercised once the price offered matches the price quoted in the limit order instead of immediate market orders and trade on other market places.

[104] In a broader context, the example could even be applied to abstinence of public transport by car-ownership to represent the off-market alternative.

In Gehrig's model both consumers and suppliers have three choices. These are a) joining an intermediary and perform a certain transaction, b) trying to find a match on a search market and start to bargain or c) do not trade at all. To simplify the setup, market participants only exchange a single product when trade happens. This construction helps to explain why and under what conditions intermediates exist and operate profitably.

In the model, consumers are distinguished by their willingness to pay. It is uniformly distributed over the unit interval such that demand is given by $D(p) = 1 - p$ with prices $p \in [0, 1]$. In the same manner, suppliers have a uniformly distributed reservation value which needs to be exceeded in order to trade This leads to a linear supply of $S(p) = p$. Both willingness to pay and reservation values are private information, but their distributions are known by all participants.

A vital prerequisite for intermediation in Gehrig's model are frictions or inefficiencies in the matching market. These frictions are incorporated such that a buyer may not find a seller or vice versa, since no market maker is coordinating trade. Therefore, both parties actively search for each other. Their success depends on the matching technology at hand. It follows that a match occurs only with some probability λ. However, this probability might be even lower as the two markets sides can differ in size. Accordingly, λ gives only the probability for those participants on the short market size, i.e. the absolutely smaller number. Those on the long side, who surmount the others in numbers, are rationed even further. Therefore, their probability to find a match is even lower and it is scaled down by the proportion of the groups' sizes.[105]

Once a trading partner is found, they have to bargain over prices. To keep matters simple, either of them offers a price to trade and the counterparty might accept it or not, depending on the condition that they obtain a non-negative surplus. In case the offer is refused, both leave the market without conducting a transaction. The rationale for either party is, thus, to quote a price such that the other party will not refuse, but at the same time to increase the spread between the reservation prices and the bids offered. Thereby, expected surplus in the matching market is

[105]See Gehrig (1993, pp. 102–103).

maximised. Formally, this can be stated (given equal participation on both sides)[106] by the sum of the surpluses for the cases where an agent can quote a bid or where an agent can respond to a quoted price. For a passenger as a buyer this expected surplus is given by:

$$\mathbb{E}\left(r_p^{SM}\right) = \frac{\lambda}{2} \int_{p_t \leq b(p_p)} \big(p_p - b(p_p)\big)\ dF(p_t) + \frac{\lambda}{2} \int_{b(p_t) \leq p_p} \big(p_p - b(p_t)\big)\ dF(p_t) \quad (3.1)$$

With r_p as a passenger's surplus, λ as the just previously introduced probability that both parties meet, p_p and p_t as the reservation prices of passengers and transport firms, respectively. The bid placed by either market side is given by $b(p_i)$ with $i \in \{p, t\}$. $F(p_t)$ describes the distribution of transport firms' reservation prices (of those transport firms active in the search market). The left term with the Lebesgue integral gives expected surplus in the case that the passenger is the bidder in the case of a match. Correspondingly, the right term accounts for natures opposite choice where the matched transport firm has the right to offer a price quote.[107] The decision space of a passenger is spanned by the bidding strategy $b(p_i)$.

For transport firms the structure of surplus is similar. However, surplus originates from the difference between the offered price and the reservation value. Therefore, expected surplus is given by:

$$\mathbb{E}\left(r_t^{SM}\right) = \frac{\lambda}{2} \int_{p_p \leq b(p_t)} \big(b(p_t) - p_t\big)\ dG(p_p) + \frac{\lambda}{2} \int_{b(p_p) \leq p_t} \big(b(p_p) - p_t\big)\ dG(p_p) \quad (3.2)$$

Where $G(p_p)$ is the distribution of passengers' maximum willingness to pay. Accordingly, surplus is composed of a part where a transport firm performs an active price quote (first term) and where it receives an offer (second term).[108]

As a result, there are two possibilities for a failure to trade in the matching market: either there appears no match due to the inefficiencies λ or the auction leads to disagreement and failure of trade.

[106] Alternatively, the distributions $F(p_t)$ and $G(p_t)$ (both introduced below) have to be conditional on having been matched. See Spulber (1999, p. 120).

[107] Note, that both integrals have equal weights meaning that the assignment of a bidder is purely random.

[108] See Gehrig (1993, pp. 103–104).

Introducing an intermediary that gathers information about buyers and sellers and accordingly sets prices to buy and sell, gives both parties a possibility to overcome the frictions of the search market. The prices quoted are fixed and publicly observable which is tantamount to everyone's awareness of these quotes. The intermediary's objective is to maximise its profit. Profit is given by the price difference for buyers and sellers, i.e. passengers and transport firms multiplied with the quantity traded:

$$\Pi = (p_a - p_b)Q \tag{3.3}$$

With p_a as ask price, p_b as bid price and Q as trading volume.[109] It it assumed that the intermediary does not hold any inventory. In consequence, buyers or sellers will be rationed if their numbers are not equal. Therefore, $Q = min(D_p, D_t)$ with D_p and D_t as the number of passengers and transport firms affiliated with the intermediary, respectively.[110] The model assumes that rationed participants join the matching market instead.[111]

To compare the intermediated market to the matching market the gains for consumers and producers must be evaluated. Values from intermediation for traders are given by:

$$\mathbb{E}\left[r_p^I(p_p)\right] = \tau_p\left(p_p - p_a\right) \tag{3.4}$$

$$\mathbb{E}\left[r_t^I(p_t)\right] = \tau_t\left(p_b - p_t\right) \tag{3.5}$$

Rationing is incorporated in these equations by the parameter τ. It gives the probability of being rationed as the minimum of the ratio between the number of traders on both sides and one. For an agent of market side i this probability is formally given by: $\tau_i = min\left(\frac{D_i}{D_j}, 1\right)$ with $i, j \in \{p, t\}$ and $i \neq j$.[112]

[109] To distinguish the intermediary's prices and those from the search market the symbols are labeled by the more general indices a and b (for ask and bid) instead of p and t above.
[110] D_p and D_t are thus demands for the intermediaries service by the two groups.
[111] See Gehrig (1993, pp. 104–105).
[112] See Gehrig (1993, p. 105) and note that $\tau_i < 1$ implies $\tau_j = 1$ and vice versa.

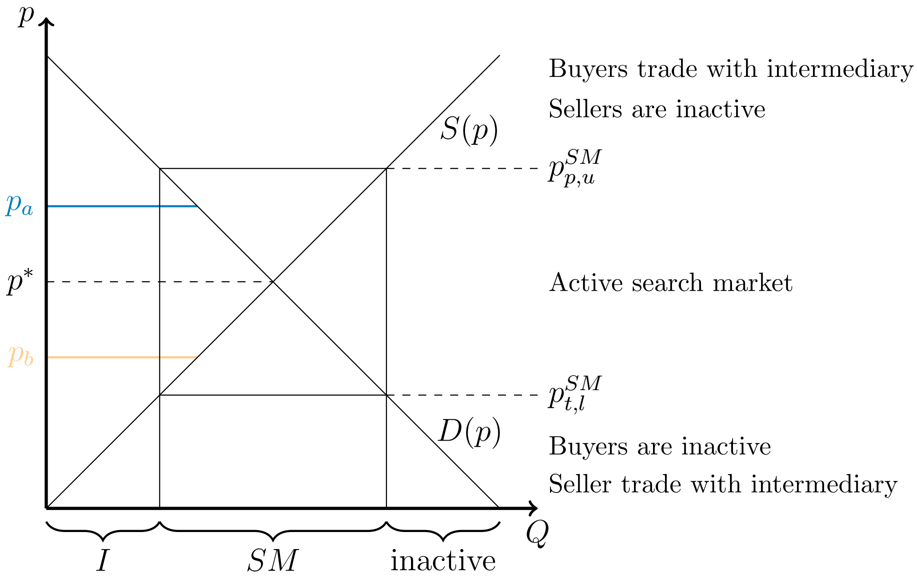


Figure 3.1: Coexistence of an intermediary and a search market

Own representation based on Gehrig (1993, p. 110).

The game that passengers, transport firm and an intermediary play has three stages: In the first, an intermediary decides on prices p_a and p_b. Then, the agents on both market sides decide whether to "join" the intermediary or the search market. Traders will choose the intermediary whenever their benefit is greater than the benefit from the matching market $r_i^I > r_i^{SM} > 0$.[113] As described above, it might happen that one market side is rationed. The rationed agents will have a possibility to trade in the search market while all others exchange services at the quoted prices. In stage three the mechanism of the search market is applied.[114]

Figure 3.1 illustrates a possible equilibrium where each market side is partitioned into three groups: a) those who trade with the intermediary (indicated by I), b) those who challenge the search market (abbreviated by SM) and c) those who ex-ante refrain from participation and are inactive as their expected surplus from either institution is negative. In Figure 3.1 these groups can be identified from left

[113]This implies that at the boundary agents prefer the matching market over intermediation.
[114]See Gehrig (1993, p. 106).

to right by the braces on the bottom. Furthermore, the graph depicts the clearing price p^* in a perfect market with no fictions at all.

The rationale of the first group for buying and selling through the intermediary is as follows: high valuation passengers will decide on using the intermediary's service as the costs in terms of the possibility of missed trades is too high in the search market. Similarly, transport firms with low reservation prices fear foregone sales in the search market. Going back to the introduction of the search market's frictions, a higher probability of successful matching reduces these search costs and increases competitive pressure on the intermediary. Therefore, the intermediary will choose a smaller spread. By the same argument, high search costs allow the intermediary to increase the spread and internalise these frictions.[115]

The question appears why the vertical line between I and SM in Figure 3.1 is left of the points where bid and ask prices cross the supply and demand functions, respectively? This can be explained by the expected surplus of the agents. As an example, the point where willingness to pay coincides with the ask price (in blue) of the intermediary helps to understand their motive. These agents obtain zero surplus from trade with the intermediary.[116] When they instead choose to join the search market there is a possibility of a transaction taking place leading to a positive surplus. Therefore, passengers select the search market as long as $\mathbb{E}[r_p^I] < \mathbb{E}[r_p^{SM}]$. Similarly, sellers expected surplus in the search market exceeds the one obtained by trading with the intermediary. Consequently, the bid price (in orange) needs to be higher.

To obtain the threshold and the prices which the intermediary charges, the optimal biding strategy of the search market participants needs to be evaluated. Expected surplus of the search market can be derived and compared to the expected surplus given trade with the intermediary. From the definition in Equation (3.1) follows that a passenger's only decision variable is the optimal price quote $b_p(p_p)$ in the

[115]See Gehrig (1993, pp. 107–111).

[116]This statement demands that no rationing by the intermediary appears. In case such an agent is rationed, expected surplus is just the expected surplus of the search market. Since rationing is arbitrary $r_p^I|_{\text{no rationing}} = 0 < \mathbb{E}\left[r_p^I\right]|_{\text{rationing}} < \mathbb{E}[r_p^{SM}]$. Therefore, the argument of the text still holds.

search market. To maximise surplus, only the left integral needs to be optimised, as the other term is outside of passenger's scope. Given the uniform distribution of those active transport firms in the search market, the objective function can be written as:

$$\int_{p_t \leq b(p_p)} \big(p_p - b_p(p_p)\big)\ dF(p_t) \tag{3.6}$$

With $F(p_t) = \frac{p_t}{p_{p,u}^{SM} - p_{t,l}^{SM}}$ and $p_{p,u}^{SM}$ and $p_{t,l}^{SM}$ as the highest willingness to pay of a passenger in the search market and, correspondingly, the lowest reservation price of a transport firm, respectively. Thus,

$$dF(p_t) = \frac{1}{p_{p,u}^{SM} - p_{t,l}^{SM}}$$

and the optimal quote can be obtained by maximising Equation (3.6) with respect to $b(p_p)$:

$$\max_{b_p(p_p)} \left[\frac{p_t}{p_{p,u}^{SM} - p_{t,l}^{SM}}\ \big(p_p - b_p(p_p)\big) \right]_{p_{t,l}^{SM}}^{b_p(p)}$$

yielding:

$$b_p(p_p) = \frac{p_p - p_{t,l}^{SM}}{2} \tag{3.7}$$

This means, a passenger should post a price that is just in the middle between his valuation and the lowest possible price a transport firm is willing to offer in the search market. The optimal quote of a transport firm follows, similarly, as:

$$b_t(p_t) = \frac{p_{p,u}^{SM} + p_t}{2} \tag{3.8}$$

Given these two bid strategies, both parties can determine their expected surplus. Therefore, the bids in Equations (3.7) and (3.8) can be substituted into the surplus functions of Equations (3.1) and (3.2). For passengers this yields:[117]

$$\begin{aligned}\mathbb{E}\left(r_p^{SM}(p_p)\right) &= \frac{\lambda}{2}\int_{p_t}^{b_p(p_p)} \left(p_p - b_p(p_p)\right)\, dF(p_t) \\ &\quad + \frac{\lambda}{2}\int_{b_t(p_{t,l}^{SM})}^{p_p} \left(p_p - b_t(p_t)\right)\, dF(p_t) \\ &= \frac{\lambda}{2}\frac{\left(p_p - p_{t,l}^{SM}\right)^2}{4(p_{p,u}^{SM} - p_{t,l}^{SM})} \\ &\quad + \frac{\lambda}{2}\frac{\left(6p_p - 5p_{p,u}^{SM} - p_{t,l}^{SM}\right)\left(2p_p - p_{p,u}^{SM} - p_{t,l}^{SM}\right)}{16\left(p_{p,u}^{SM} - p_{t,l}^{SM}\right)}\end{aligned} \tag{3.9}$$

By the same reasoning, transport firms' expected surplus is:

$$\begin{aligned}\mathbb{E}\left(r_t^{SM}(p_t)\right) &= \frac{\lambda}{2}\int_{b_t(p_t)}^{p_{p,u}^{SM}} \left(b_t(p_t) - p_t\right)\, dG(p_p) \\ &\quad + \frac{\lambda}{2}\int_{p_t}^{b_p(p_{p,u}^{SM})} \left(b_p(p_p) - p_t\right) dG(p_p) \\ &= \frac{\lambda}{2}\frac{\left(p_{p,u}^{SM} - p_t\right)^2}{4\left(p_{p,u}^{SM} - p_{t,l}^{SM}\right)} \\ &\quad + \frac{\lambda}{2}\frac{\left(p_p + 5p_{t,l}^{SM} - 6p_t\right)\left(p_p + p_{t,l}^{SM} - 2p_t\right)}{16\left(p_{p,u}^{SM} - p_{t,l}^{SM}\right)}\end{aligned} \tag{3.10}$$

As the original question is where the threshold between the search market and the intermediary is, only passengers and transport firms with the highest and lowest valuation (of those in the search market) matter, respectively. Thus, substituting $p_p = p_{p,u}^{SM}$ into Equation (3.9) and $p_t = p_{t,l}^{SM}$ into Equation (3.10) gives surplus for

[117]Note, the model presented deviates at this point from Gehrig's line of thought. While Gehrig conditions in his formulations ex ante that the expected value of receiving a bid (the second integral in Equation (3.9)) is conditioned on the lowest reservation value of a transport firm being active in the search market $p_{t,l}^{SM}$, the present model lacks this pre-multiplied Delta Dirac function. Gehrig's expected surplus would be: $\mathbb{E}\left(r_p^{SM}\right) = \frac{\lambda}{8}\frac{1}{p_{p,u}^{SM} - p_{t,l}^{SM}}\left((p_p - p_{t,l}^{SM})^2 + (2p_p - p_{p_u}^{SM} - p_{t,l}^{SM})^2\right)$.
Instead, the formulation in Equation (3.9) contains with the very right term the true expected surplus when the other market side is given the right to post an offer. However, the pivotal results with regard to trading volume are maintained in both models as will be shown below. Cf. Gehrig (1993, pp. 117–119).

the marginal subjects. It can easily be shown that these values are exactly the same due to the symmetric setup of the demand and supply functions.

$$\mathbb{E}\left(r_p^{SM}(p_{p,u}^{SM})\right) = \mathbb{E}\left(r_t^{SM}(p_{t,l}^{SM})\right) = \frac{5\lambda(p_{p,u}^{SM} - p_{t,l}^{SM})}{32}$$

To determine the threshold, surpluses need to be compared to the surplus of either party when trading with the intermediary. The latter functions are given by Equations (3.4) and (3.5). The system of equations to be solved reads as:[118]

$$\begin{aligned}\frac{5\lambda(p_{p,u}^{SM} - p_{t,l}^{SM})}{32} &= p_{p,u}^{SM} - p_a\\ \frac{5\lambda(p_{p,u}^{SM} - p_{t,l}^{SM})}{32} &= p_b - p_{t,l}^{SM}\end{aligned}$$

Given the linear demand and supply structure of the intermediary, it is clear that $1 - p_a = p_b$, thus, the threshold between the search market and the intermediary lies at:[119]

$$p_{p,u}^{SM} = \frac{32p_a - 5\lambda}{2\,(16 - 5\lambda)}$$

for passengers and:

$$p_{t,l}^{SM} = \frac{32 - 32p_a - 5\lambda}{2\,(16 - 5\lambda)} \tag{3.11}$$

for transport firms. As the latter threshold is equivalent to transport firm's supply at this price, it corresponds to the trading volume as well. Consequently, the intermediaries profit function can be written as:

$$\Pi = (p_a - p_b)p_{t,l}^{SM}$$

[118] The result is robust with respect to rationing, therefore τ_p and τ_t can be omitted at this point.

[119] Gehrig (1993, pp. 118–119) proofs that even under rationing the bid and ask prices are symmetric to the Walrasian price p^*.

Once again, substitution of p_b by $1 - p_a$ and maximising of the objective function yields the optimal bid and ask prices of the intermediary. These follow as:

$$p_a^* = \frac{3}{4} - \frac{5\lambda}{64}$$
$$p_b^* = \frac{3}{4} + \frac{5\lambda}{64}$$

This means, the spread an intermediary offers depends only on the uncertainty in the search market. The higher the probability of a match, the lower the spread as the competitive pressure from the search market is put on an intermediary. However, due to the uncertainty of the matched partner's type, trade may even fail (in the search market) under $\lambda = 1$. This explains, why an intermediary offering *certain* transactions remains to exist in this extreme case.

The intermediary's volume of trade can at last be determined by substituting equilibrium prices back into the threshold in Equation (3.11):[120]

$$p_{t,l}^{SM} = Q = \frac{1}{4}$$

The threshold between those who are active in the search market and those who deal with the intermediary also determines the groups of inactive passengers and sellers. The boundary between these groups is depicted by the right vertical line in Figure 3.1.

Taking passengers' point of view, all passengers that have a willingness to pay that is greater than the level of indifference between the search market and the intermediary (denoted by the upper horizontal line in the graph) will use the intermediary's service. Thus, those transport firms having a reservation value greater then this threshold $p_{p,u}^{SM}$ will not find any passengers in the search market willing to trade. Therefore, they have a non-positive expected surplus from entering the search market and consequently remain absent. Similarly, passengers with willing-

[120] Note, that this result is identical to the result obtained by Gehrig. However, due to the increased uncertainty within the present model, the spread is always greater than in Gehrig's case.

ness to pay lower than $p_{t,l}^{SM}$ fail to find an appropriate partner in the search market as transport firms with low reservation prices will trade through the intermediary.[121]

This example illustrates that both the security and immediacy an intermediary offers allow for a market where a middleman can coexist with a search market. However, the characteristics of travel are not accounted for. This motivates a deeper analysis of the model's limits.

Limitations of the intermediation model in personal transport

From the discussion of the decisions in travel[122] follows that the choices to be made differ in their impact on short term mode choice. Once the decision to travel from one place to another is made, travellers' objectives are to reach the destination given their budget constraint. In a simplified setting, this can be interpreted as the price per time unit. This implies that at short distances media, such as bicycles, are superior to mass-transit which may be bound to discrete stops and timetables. The question for the traveller is ultimately which medium or which combination of modes to use? The problem is reduced to a constrained maximisation.

However, travellers perceive only some of the offered services' characteristics. True cost, schedules, availability or comfort are among those characteristics where information asymmetries can occur. In the presented model travellers can choose between an intermediary and a matching market. To account for a plus of information offered by an intermediary the probability of match λ could also be interpreted as factor of uncertainty with regards to the underlying transport service. This raises the question on how information is generated in the first place? An approach would be that external sources in the sense of APIs for live traffic data or schedules are tapped. Then endogenous information is generated depending on users' travel offers and demands. Beyond that, the setting focusses on competition of two inherently different market mechanisms while competition from another intermediary is left aside.

[121] Note that the described equilibrium is not unique as expectations in this Bayesian game might be unfavourable for an intermediary such that all trade occurs on the search market. See Gehrig (1993, pp. 106–111).

[122] Cf. Figure 2.1 in Chapter 2.

To overcome these drawbacks, multiple alternatives are discussed in the following two chapters. Starting with a competition setup relying on differentiation and followed by user-based added value in terms of network effects.

4 Non-price competition

The problem of competing in prices is that rival firms have incentives to reduce their prices in order to gain market shares. This leads to a self-reinforcing cycle: all competitors quote prices that underbid each other resulting at a theoretical market price at the level of marginal cost resulting in at most zero profits for firms. To overcome this most fierce and ruinous form of competition firms search for ways to avoid this Bertrand competition.

On a general level, firms can either change their supply structure or have to look for ways to increase demand (for their own products). On the supply side, they can choose to enhance their production processes and reduce costs or change their products' characteristics. This latter approach is pursued in the next two sections. First, a review on different lines of thought on differentiation is given, before the vertical approach is analysed in depth along a generalised model.

In Chapter 4.3, the solution to the Bertrand paradox takes the way of how to canalise demand in order to reduce competitive pressure instead of changes in supply. The central tool to bind and increase demand for a firm's products and services are network effects which are described below.

4.1 Differentiation

4.1.1 From horizontal differentiation over monopolistic competition to Lancaster

Horizontal differentiation

Among the first milestones in non-price competition was the model by Hotelling (1929). He introduced a cost of transport into the surplus function of consumers. Thereby, not only price, but also the location of a seller became determinants for consumers' decisions. In the model's simplest form, consumers are uniformly distributed along a unit line, for instance a street, with unit mass. In all other respects consumers are similar, such as having the same willingness to pay. Two firms compete in prices for consumers by locating somewhere along that line. Most consumers will have to travel to reach either firm and purchase the product. When maximising surplus, consumers take both their cost of travel and price into account. Thus, firms have to decide on both location and price.[123]

Assuming quadratic transport cost as introduced by Gabszewicz and Thisse (1979), the non-price dimension receives more weight. A pivotal result constitute the two opposing effects: the first pushes competitors towards the center of demand to reduce the distance to all consumers and, thus, (quadratic) transport cost. However, when firms are drawn towards the center by this "demand effect" price competition becomes fiercer as differentiation between firms dies away. In conclusion, competitors have to balance the effects of supplying more consumers and decreasing prices by price competition. Above these effects stands the insight that by spatial differentiation a ruinous Bertrand competition can be relaxed and positive profits are viable.[124]

The versatility and popularity of Hotelling's model stems from the interpretation of location as a means of horizontal differentiation. Horizontal differentiation

[123] See Gabszewicz and Thisse (1979) and note that the costs of travel are fundamental to the model's results. In the original case by Hotelling these were linear while Gabszewicz and Thisse assume that they rise quadratically in distance. The latter version is adapted below.

[124] See (Woeckener, 2014b, pp. 136–139).

comprises both spatial differences and tastes. Thereby, the model is applicable to a wide range of markets where only preferences in style and taste are heterogeneous.

Issues, such as where to sell products, are obviously the original idea. However, determining colors, flavours or design of a product to be sold can easily be answered by this approach as well. When it comes to other differences in products, such as storage capacities, the Hotelling approach reaches its limits.

Monopolistic competition

The theory of monopolistic competition by Chamberlin (1965)[125] argues along market definition and assumes that products contain some degree of monopoly due to differentiation. Thus, individual demand can deviate from aggregate (product group) demand leading to profits. The second argument for differentiation besides heterogeneous (horizontal) preferences are "improvements in product". By this, Chamberlin means an upwards shift in average costs. This leads to a concomitant rise in demand for that product and possibly to more sales and profits.[126]

Unfortunately, the theory of monopolistic competitions gives little information on consumers' rationale for purchasing a certain product as differentiation in products is only implied and not explicitly modelled. Strategic effects from the firms' point of view can only be analysed superficially as there is no parameter determining differentiation. This drawback passes into analyses of prices and market shares as the pivotal issue of determining demand functions remains open.[127]

Characteristics model

Finally, the characteristics approach by Lancaster (1966) is based on disassembling products into their characteristics and their respective specifications. Assuming that goods can be divided into their characteristics, each product can be identified

[125] First edition was published in 1933.

[126] See Chamberlin (1965, pp. 95–97). To some degree this corresponds to vertical differentiation as it will become clear below.

[127] Note that Chamberlin distinguishes between global demand for all suppliers and the local demand curve of the individual differentiated good or service. See also (Chamberlin, 1965, p. 113–116).

as a point in the (multidimensional) characteristics space. Then, consumers have to decide which version of a good to consume.

If possible, a rational consumer will choose the good with his preferred specifications if possible. Otherwise, when this specification is not offered, the consumer will select the version that is *closest* to his most preferred specification. This seems similar to Hotelling's model, but instead of a transport cost parameter to account for the mismatch, the so called compensating ratio and the assumption of convex indifference curves incorporate the mismatch. The characteristics ratio is defined as how much more of an available product would be needed to compensate for the mismatch. Therefore, the *closest* version is the one with the lowest characteristics ratio.[128]

Assuming the characteristics space is determined by a convex set, the specifications can be scaled up (or down).[129] Giving consumers the opportunity of purchasing multiple items of the *same* specification yields a linear transformation and, thus, they reach a higher indifference curve. This is a fundamental difference to the spatial models of horizontal and vertical differentiation as these models generally assume single purchases only.[130]

One is inclined to combine products with different specifications. However, this may only be possible with divisible goods. To illustrate this limitation of divisibility more drastically, it can be said that two motorcycles do not make a car.[131] An implication of this is that quality and spatial competition are only applicable to indivisible goods or services. Otherwise, a combination of goods with the respective characteristics ratios and prices could serve as viable substitute and Lancaster's approach could be used.[132]

Whilst the three approaches to product differentiation all have their validity for circumstances where differentiation is horizontal (Hotelling), demand elasticities

[128]See Lancaster (1979, pp. 37–41).
[129]For details and further assumptions cf. Lancaster (1979, pp. 24–29).
[130]Cf. Chapter 4.1.2 for vertical differentiation below.
[131]This statement is an adaption of Rosen (1974, p. 38) who wrote: "two 6-foot cars are not equivalent to one 12 feet in length, since they cannot be driven simultaneously".
[132]See Lancaster (1979, pp. 26–32).

are known (Chamberlin) or the products and services are easily compartmentalised (Lancaster), the services offered by mobility intermediaries hardly fit into these categories:

- The Hotelling approach drops out as design aspects beyond an expedient Graphical User Interface (GUI) are presumed to be of limited relevance and real locations do not matter for ubiquitous mobile services.

- Strategic behaviour between competitors and determinants of their actions are hard to incorporate into the monopolistic competition environment. Therefore, this theory drops out as a starting point for the transport intermediation setting.

- And finally, the characteristics approach may be applicable, but to keep the calculations simple the means of investigations is a setup that is commonly used in models of vertical differentiation.

4.1.2 Vertical differentiation

In contrast to Hotelling's spatial (horizontal) competition model, vertical differentiation models consider differentiation in terms of quality offered. Therefore, vertical differentiation and quality differentiation are used synonymously. In quality differentiation models, it is assumed that prices and qualities are imperfect substitutes. Otherwise, consumers conceive quality as a mere reduction or rise in price and the strategic effect between the two dimensions vanishes.[133] Thus, demand is a function of both price $p \in \mathbb{R}_+$ and a quality measure $s \in \mathbb{R}_+$: $D(p, s)$.[134]

So far, this sounds rather similar to Hotelling's model where demand is also a function of price and a spatial parameter. However, demand is no longer assumed

[133] See Tirole (1988, p. 101).
[134] Cf. Dorfman and Steiner (1954, p. 832).

to be (necessarily) exogenous, i.e. not all consumers make ex ante a purchase. Therefore, consumer surplus is generally described as:

$$r(s, p) = W(s) - p, \tag{4.1}$$

with $W(s)$ defining some willingness to pay for a certain level of quality s. It is straight forward that once this first term is lower than price, surplus becomes negative and consumers refrain from consumption. Thus,

$$r(s, p) = \begin{cases} 0 & \text{for } W(s) \leq p \text{ and} \\ W(s) - p & \text{otherwise.} \end{cases}$$

It must be noted that similar to Hotelling, most models on vertical differentiation are based on price competition. A few exceptions are Gal-Or (1983) and Motta (1993) who compare Bertrand and Cournot settings. Both authors agree on lower (higher) differentiation under Cournot (Bertrand) competition which complies with the rationale taught by Hotelling's transport costs in the horizontal setting. However, Gal-Or further analyses effects on demand and surplus while Motta focuses on the impact of costs on profits.

Gal-Or finds that Cournot competition leads to both lower differentiation and lower average quality levels. She shows that two ambiguous effects appear: a) more consumers will purchase the product, but b) quality reduction reduces overall surplus.

Having fixed costs, Motta (1993) demonstrates the puzzling result that profits are higher for Bertrand competition than in Cournot competition. With variable costs, the relation is *back to normal* and profits are higher under Cournot competition (while products are still less differentiated).

Quantity competition is not appropriate for (electronic) service industries that can be scaled up easily. Therefore, analyses on intermediation in personal transport are preferably conducted in Bertrand settings. In the remainder, dominantly price competition settings will be analysed and the discussion of Cournot competition in vertically differentiated markets is only briefly taken up again in Chapter 5.6.

4.1.3 Quality measure

Before analysing the consequences of this surplus function, the quality measure has to be discussed. In both marketing and economics literature it is suggested to interpret this quality as a multidimensional variable. To some extend, this is similar to Lancaster's characteristics model. In economics Shapiro (1982, p. 21), for example, states "durability", "safety" or "speed of service" as possible dimensions of product and service quality. Or Sheshinski (1976, p. 127) who further suggests in the context of personal transport "frequency of travel", "space provision" and "aesthetic aspects".[135]

A marketing approach to service quality

In the marketing literature it has been established to model quality as a multi-dimensional measure by looking at product characteristics. The pivotal questions for researchers is to find the factors that consumer value the most in products. Therefore, Parasuraman, Zeithaml, and Berry (1988) introduced the Service Quality Measure (SERVQUAL)-measure, which is comprised of five (sub-)dimensions. Namely, these are:[136]

- "Tangibles: physical facilities, equipment, and appearance of personnel".
- "Reliability: ability to perform the promised service dependably and accurately".
- "Responsiveness: willingness to help customers and provide prompt service".
- "Assurance: knowledge and courtesy of employees and their ability to inspire trust and confidence".

[135] The term "aesthetic aspects" is mostly misleading in the context of quality, as design is a subjective matter and preferences are certainly heterogeneous among consumers. Therefore, the term should be shifted to realm of horizontal differentiation.
[136] See Parasuraman et al. (1988, p. 23).

- "Empathy: caring, individualised attention the firm provides its customers".

However, applications of the SERVQUAL-measure have not been successful per se: analyses of different industries showed that only the dimension *Reliability* resulted in significant[137] estimates for a quality impact in purchases.[138] This leads to the conclusion that SERVQUAL does not yield satisfying results. Other researchers altered the setup of the very method by exchanging the underlying questionnaire and categorised the attributes into new sub-dimensions.[139]

The results of these quality dimensions' assessments are, however, mostly similar in that one or two sub-dimensions yield significant estimates. Taken together, service quality is mostly driven by limited characteristics of the service or as the preceding research by Churchill and Surprenant (1982, pp. 501-503) has shown, only the performance of a service matters. By the same argument, the results of the briefly discussed papers vindicate the findings of Churchill and Surprenant.

In practice there are quality indices that boil down many dimensions into a single one, but these are mostly based on easily measurable characteristics.[140] The discussed marketing approaches, however, help firms to identify valued product or service characteristics, but they lack building a comparable index. Even in the case such an index would be provided, consumers cannot fully perceive the content and design of such indices. Therefore, sticking to one dimension reduces complexity and interpretation as a proper scale can be applied.

For a model in vertically differentiated markets, it is, consequently, pivotal to establish a common understanding of quality. Above, consumers' evaluation of quality must go in the same direction. This means, all consumers agree that a higher quality is always preferable, but the valuation in terms of willingness to

[137] At the 1%-level.

[138] The industries analysed were banking, credit cards, maintenance and telephone. On the 10%-level *Assurance* was also significant for all industries.

[139] Examples are Cronin and Taylor (1992) or Treen, Pitt, Bredican, and Farshid (2017) for an analysis of mobile applications' service quality.

Interestingly, Treen et al. (2017, pp. 122-123) find that the "order of importance to consumers is reliability, personal and then visibles" which comes as a results of the weights obtained in the regression performed. Thereby, the vertical factors, i.e. performance factors, are perceived by customers as more important than *visibles*, i.e. preference factors.

[140] Benchmarks of computer hardware may be an example.

pay for quality is dissimilar. A common textbook example beyond the present intermediation context is painkillers and the dose or the time they last as the fundamental quality criterion.[141] Thus, consumers' willingness to pay for a quality level determines the product or service chosen. Willingness to pay can, ultimately, be narrowed down to income or as Motta (1993, p. 115) puts it, "the preference parameter [of a consumer] can be interpreted as the marginal rate of substitution of quality and income".[142] Consequently, heterogeneity in income allows for services of different quality to coexist on the market.

Quality criteria in travel intermediation

In a mobility intermediation market, the base value created by intermediaries is that travellers get to know about connections and their duration. Thus, by using an intermediary, travellers expect better information and, thereby, a reduction in their travel time and ultimately about saving money — as prices for different modes are quoted. By formulating the quality dimension as an expected travel time reduction, several other factors of quality are taken into account as well:

- Network effects: the more transport firms there are, the more likely it is for the intermediary to find the quickest connection (cf. Chapter 4.3 below).
- App performance: taking the time of using the service into account gives rise to the superiority of quick services. By the same token, the disappearance of travel agencies and hotline services can be explained as the time effort to obtain information was comparatively larger.

Going one step ahead, the expected time saving can be converted into expected total price reductions by assuming a value of time factor for travellers. As the transport literature suggests, time value for travellers is heterogeneous.[143] To account for these differences among travellers, it makes sense to model this valuation

[141] See Woeckener (2014b, p. 168).
[142] See Tirole (1988, p. 96) as the source used by Motta.
[143] See Jara-Díaz (2007, pp. 41-80) for a detailed introduction on travel time valuation. There is ample research on point estimates of travel time valuation, see e.g. Abrantes and Wardman (2011), Shires and De Jong (2009) or Zamparini and Reggiani (2007). All of these studies compare the estimates of travel time valuation or the valuation of saved travel time. They

as a continuously distributed variable. Keeping the model simple, this time value is modelled as an uniformly distributed variable. It will be formally introduced in Chapter 6.1 below.

A drawback of this approach is that for travellers gross travel prices, i.e. the overall price charged for both the intermediary's service and the actual ticket, are beyond the model's scope. However, it can be assumed that the willingness to pay for time savings through an intermediary is (strongly) positively related to the willingness to pay for speedy transport solutions. This means, somebody who is eager to know the best way to get, for example, from Munich's city center to the airport just outside the city and is willing to pay a high amount of money for that information, will presumably be willing to pay a premium for (trans-)rapid transport. Therefore, this issue must be noted, but focussing on the role of intermediaries puts the mere willingness to pay for their services first.

Before continuing with demand side solutions to the Bertrand paradox, quality differentiation is reviewed in depth along a general model. Thereby, the formal basis for the platform model in Chapter 6 is developed.

4.2 A general model on vertical differentiation

Up until now, quality has only been analysed in absence of an analytical model. Therefore, strategic situations with few sellers competing for market shares where quality is the additional strategic variable beyond price are discussed. The arising questions in such settings are profit maximisation or welfare analyses in terms of satisfied demand, prices and qualities. In the canonical model by Gabszewicz and Thisse (1979) two firms $i \in \{1, 2\}$ compete over prices and quality. Taking preference for quality θ to be uniformly distributed over the unit interval and the surplus function in (4.1) with $W(s) = \theta \cdot s$ demand can be derived for each firm. θ can be interpreted in the transport setting as the valuation of the time saved by

show that there exists ample variation in the estimates which corroborates the fact that the time value of saved time is different among travellers.

For a general discussion on time valuation see DeSerpa (1971).

booking rides through a sales channel. Thus, $W(s)$ is the monetary valuation per unit of time θ multiplied by the time saved s. This results in a pecuniary number.

As noted above, demand may follow endogenously. This opens the possibility that prices are too high for some (all) consumers who do not purchase at all. By the same argument, prices may be low enough having all consumers purchase one unit. The question of from whom they buy follows immediately.

The analysis by Gabszewicz and Thisse (1979, pp. 346–347) gives three market situations, to which one has to be added:[144]

1. One firm is a monopolist catering all consumers.

2. Two firms woo for consumers having all of the latter served.

3. Two firms just manage to coexist and all consumers buy from either firm. This case is due to Wauthy (1996). However, this case requires further explanations as it departs from the economic rationale of the other cases.[145]

4. The textbook case where some consumers refraining from consumption and both duopolists competing for market shares concludes the analysis.

Following the arguments by Wauthy (1996), heterogeneity in consumer willingness to pay[146] determines the market outcome. Therefore, let $\theta \sim U(\theta_l, \theta_u)$ with unit mass and θ_l and θ_u as the lowest and highest value for the willingness to pay (per unit of the quality measure s), respectively.[147] Together with consumers' surplus functions when purchasing from firm i

$$r_i = \theta s_i - p_i$$

[144]See Wauthy (1996, p. 347).
[145]See below.
[146]Wauthy (1996, pp. 346 & 352) describes the heterogeneity as "taste for quality" and "consumers' tastes".
[147]This model is similar in most respects to Shaked and Sutton (1982), but it differs in that the market size is fixed by the unit mass assumption. In contrast, Shaked and Sutton work with a constant density of one and variable limits of the distribution. Cf. Shaked and Sutton (1982, p. 4) and Wauthy (1996, p. 346).

Table 4.1: Demand in vertically differentiated markets

	D_1	D_2	$D_1 + D_2$
Preempted market	0	1	1
Covered market	$\frac{1}{\Delta\theta}\left(\frac{p_2-p_1}{s_2-s_1} - \theta_l\right)$	$\frac{1}{\Delta\theta}\left(\theta_u - \frac{p_2-p_1}{s_2-s_1}\right)$	1
Uncovered market	$\frac{1}{\Delta\theta}\left(\frac{p_2-p_1}{s_2-s_1} - \frac{p_1}{s_1}\right)$	$\frac{1}{\Delta\theta}\left(\theta_u - \frac{p_2-p_1}{s_2-s_1}\right)$	< 1

the three general demand configurations[148] can be specified by finding the indifferent consumers (in terms of θ). The results are summarised in Table 4.1 with $\Delta\theta = \theta_u - \theta_l$ and they are illustrated in Figure 4.1.[149]

The game played by the two competing firms is a two stage game where decisions on quality are made in the first stage which is followed by Bertrand competition in stage 2. Therefore, firms have ample incentive to avoid similar quality choices. The two-stage game is then solved recursively.

Setting up the corresponding profit functions for both firms (assuming zero cost) and maximising these yields the following set of reduced price functions:

- In the preempted market, firm 1 will make no profits as it has zero demand, thus, it cannot offer a competitive price.[150] Despite being a monopolist, the high quality firm cannot set its price at will, but it has to maintain a higher surplus for its customers in comparison to firm 1 to avoid entry. Thus, the condition for preemption is that $r_2|_{\theta_l} \geq r_1|_{\theta_l, p_1=0}$ or equivalently $\theta_l s_2 - p_2 \geq \theta_l s_1$, which reduces to:

$$p_2 \leq \theta_l(s_2 - s_1)$$

[148]The demand in the delicate case mentioned above corresponds at this point to a covered market situation as in the second case.

[149]For the remainder it is assumed that firm 2 will offer the higher quality, i.e. $s_2 > s_1$. Furthermore, the case were both firms provide the same level of quality ($s_1 = s_2$) will be ruled out, as this reduces the model to standard Bertrand competition without profits.

[150]Note, in a two-sided setting (cf. Chapter 5) the implicit assumption of non-negative prices might be dropped, which may be used to challenge preemption.

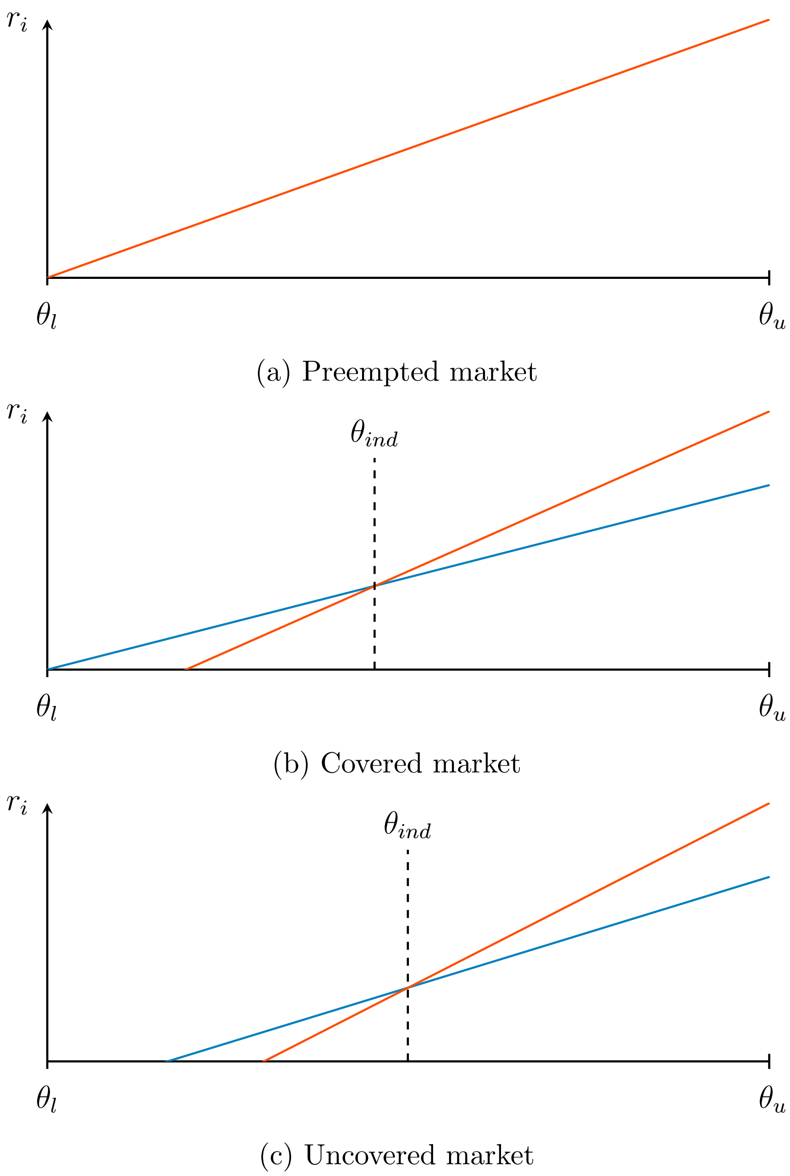


Figure 4.1: Market configurations in quality competition

High quality firm in red and low quality firm in blue

- In the covered market, straight forward maximisation yields the following prices:

$$p_1^{CM} = \frac{\theta_u - 2\theta_l}{3}(s_2 - s_1) \tag{4.2}$$
$$p_2^{CM} = \frac{2\theta_u - \theta_l}{3}(s_2 - s_1) \tag{4.3}$$

- And in an uncovered market, reduced prices are given as:

$$p_1^{UM} = \theta_u(s_2 - s_1)\frac{s_1}{4s_2 - s_1} \tag{4.4}$$
$$p_2^{UM} = \theta_u(s_2 - s_1)\frac{2s_2}{4s_2 - s_1} \tag{4.5}$$

- As mentioned above, there is a fourth market configuration that will occur when preferences are rather dispersed such that the solution of the covered market would yield a negative surplus:

$$p_1^{CM} > \theta_l s_1$$

This implies, firm 2 being a monopolist (and the solution of the preempted market applies). However, it makes sense for firm 1 to set a price just equal to the willingness to pay of consumer with the lowest valuation θ_l, i.e. $\theta_l s_1 - p_1^{JCM} = 0$.[151] The bound for this price is at the point where r_1^{CM} is just zero:

$$\theta_l s_1 - p_1^{CM} = 0$$
$$\theta_l s_1 - \frac{\theta_u - 2\theta_l}{3}(s_2 - s_1) = 0$$
$$\frac{\theta_u}{\theta_l} = \frac{2s_2 - s_1}{s_2 - s_1}$$

[151] Where the exponent JCM denotes this just-covered solution.

Table 4.2: Boundaries of market configurations I

	Preempted Market	Covered Market	Just-Covered Market	Uncovered Market
$\frac{\theta_u}{\theta_l}$	$(1,2]$	$\left(2, \frac{2s_2-s_1}{s_2-s_1}\right)$	$\left[\frac{2s_2-s_1}{s_2-s_1}, \frac{4s_2-s_1}{s_2-s_1}\right]$	$\left(\frac{4s_2-s_1}{s_2-s_1}, \infty\right)$

On the other side, it is known that p_1^{UM} cannot be lower than (or equal to) $\theta_l s_1$ as otherwise the market would no longer be uncovered. Thus, for $p_1^{UM} = \theta_l s_1$ the corner solution may be relevant:

$$\begin{aligned} \theta_u(s_2 - s_1)\frac{s_1}{4s_2 - s_1} &= \theta_l s_1 \\ \frac{\theta_u}{\theta_l} &= \frac{4s_2 - s_1}{s_2 - s_1} \end{aligned}$$

The high quality product's price will be:

$$p_2^{JCM} = \frac{1}{2}\left(\theta_u(s_2 - s_1) + \theta_l s_1\right) \tag{4.6}$$

To sum up these cases, the corner solution where $p_1^{JCM} = \theta_l s_1$ is the price charged by the low quality firm is applicable in the interval $\frac{\theta_u}{\theta_l} \in [\frac{2s_2-s_1}{s_2-s_1}, \frac{4s_2-s_1}{s_2-s_1}]$. Similarly, the lower bound for the covered market follows from:

$$\begin{aligned} p_1^{CM} &= p_1^{PM} \\ \frac{\theta_u - 2\theta_l}{3}(s_2 - s_1) &= 0 \\ \frac{\theta_u}{\theta_l} &= 2 \end{aligned}$$

In Table 4.2 all intervals for the possible market situations are given.

Now, that the prices are determined the second stage, i.e. the simple quality game without costs can be assessed. Firm 2 will choose $s_2 = s_{max}$ as its price increases over quality in all market configurations.[152] For the low quality firm, the distinction in four cases applies again:

- In an uncovered market, the optimal quality follows immediately from maximising the reduced profit function, which was first shown by Choi and Shin (1992):

$$s_1^{UM} = \frac{4}{7} s_2^{UM} \tag{4.7}$$

  This means that in an uncovered market the low quality firm will set its quality as a constant fraction of the competitor's choice.

- The low quality firm's profit in the just covered market can be restated using D_1^{CM} (cf. Table 4.1) and the prices p_1^{JCM} and p_2^{JCM}. Maximisation and (some tedious) reformulations yield:

$$s_1^{JCM}(s_2^{JCM}) = s_2^{JCM} \left(1 - \frac{\sqrt{\theta_l}}{\sqrt{\Delta\theta}}\right) \tag{4.8}$$

[152]Formally, this can be shown by:

$$\frac{\partial p_2^{UM}}{\partial s_2} > 0, \qquad \frac{\partial p_2^{JCM}}{\partial s_2} > 0, \qquad \frac{\partial p_2^{CM}}{\partial s_2} > 0 \qquad \text{and} \qquad \frac{\partial p_2^{PM}}{\partial s_2} > 0$$

The derivations are straight forward, except for $\frac{\partial p_2^{UM}}{\partial s_2} > 0$. This result follows from the quotient rule:

$$\begin{aligned} \frac{\partial p_2^{UM}}{\partial s_2} &= \theta_u \left[\frac{(4s_2 - 2s_1)(4s_2 - s_1) - (2s_2^2 - 2s_1 s_2) \cdot 4}{(4s_2 - s_1)^2}\right] \\ &= 2\theta_u \left[\frac{4s_2^2 - 2s_1 s_2 + s_1^2}{(4s_2 - s_1)^2}\right] = 2\theta_u \left[\frac{(2s_2 - s_1)^2 + 2s_2 s_1}{(4s_2 - s_1)^2}\right] > 0 \end{aligned}$$

and from the demand function above:

$$\frac{\partial D_2}{\partial s_2} \geq 0$$

Table 4.3: Boundaries of market configurations II

	Preempted Market	Covered Market	Just-Covered Market	Uncovered Market
$\frac{\theta_u}{\theta_l}$	$(1, 2]$	$(2, 8)$	$(5, 10)$	$(8, \infty)$

- From the low quality firm's reduced profit function in a covered market follows immediately maximum differentiation:

$$\Pi_1^{CM}(s_1^{CM}, s_2^{CM}) = \frac{1}{\Delta\theta}\left(\frac{\theta_u - 2\theta_l}{3}\right)^2 (s_2^{CM} - s_1^{CM}) \tag{4.9}$$

since $\frac{\partial \Pi_i^{CM}}{\partial s_1^{CM}} < 0$.

It remains to reinsert the optimal values back into the boundaries. Table 4.3 shows the results, which require further explanation. Both the boundaries of the covered market and the just-covered market as well as the boundaries of the just-covered market and the lower boundary of the uncovered market overlap. Therefore, firms struggle to identify what market situation they are in and what actions to take.

To solve this issue, a view on profits (as the firm's ultimate goal) sheds light on the optimal decision. Starting with the choice between an uncovered market and the corner solution within the overlapping interval $\frac{\theta_u}{\theta_l}$. At $\frac{\theta_u}{\theta_l} = 10$ the profit of firm 1 in the uncovered market is greater than in the just covered market $\Pi_1^{JCM} < \Pi_1^{UM}$. On the contrary, for $\frac{\theta_u}{\theta_l} = 8$ the situation is just the other way round as $\Pi_1^{JCM} > \Pi_1^{UM}$. This leads to the conclusion that within this interval there must be a point where profits are equal. The threshold can be found by plugging $\frac{\theta_u}{\theta_l} = \xi$ into the respective profit functions. Some computations lead to the solution:[153]

$$\xi = 2\left(6 + 3\sqrt{2} \cdot \sqrt{6(2 + 2\sqrt{2})}\right) \approx 8.6581 \tag{4.10}$$

[153] See Appendix C.1 for a solution sketch.

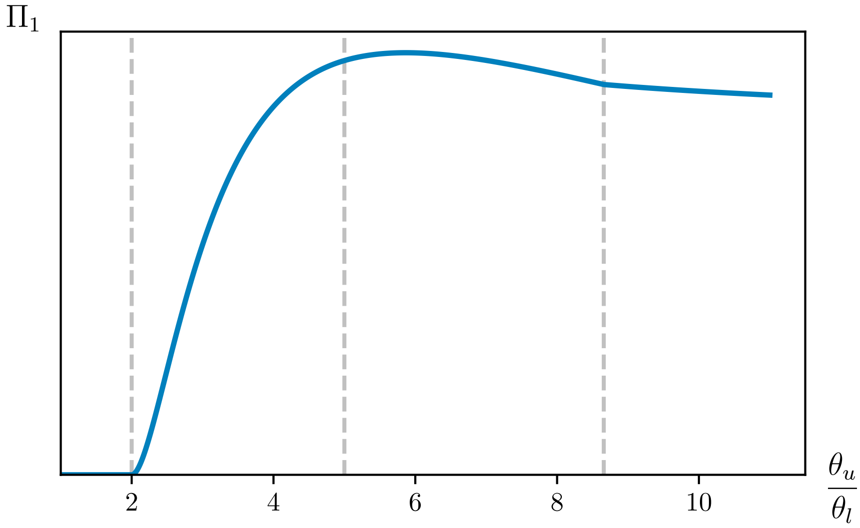


Figure 4.2: Low quality firm's profits

For the low quality firm, the just-covered market will be superior to the covered market solution over the whole range, where it is applicable, i.e. $[5, 10]$. At the lower end $\frac{\theta_u}{\theta_l} = 5$ profits are equal for both situations.[154]

Firm 1 will set its quality as low as possible to achieve maximum differentiation as shown in Equation (4.9). However, there is a constraint following from the boundaries of the covered market $\frac{\theta_u}{\theta_l} \in \left(2, \frac{2s_2+s_1}{s_2-s_1}\right)$. Solving the upper bound for s_1 yields:

$$\frac{\theta_u}{\theta_l} < \frac{2s_2 + s_1}{s_2 - s_1}$$
$$s_1 > s_2 \frac{\theta_u - 2\theta_l}{\theta_u + \theta_l}$$

Note, that quality s_1 approaches zero as the distribution narrows. At the lower limit, when it reaches zero, the transition to a preempted market is marked.[155]

[154] A short proof is presented in the Appendix C.2.
[155] For the profit, there is a similar behaviour, as with $\frac{\theta_u}{\theta_l}$ decreasing, the second term Equation (4.9) goes to zero, too.

Table 4.4: Demands in vertically differentiated markets

	Preempted Market	Covered Market	Just-Covered Market	Uncovered Market
D_1	0	$\frac{1}{\Delta\theta}\left(\frac{p_2^{CM}-p_1^{CM}}{s_2-s_1}-\theta_l\right)$	$\frac{1}{2}-\frac{\sqrt{\theta_l}}{2\sqrt{\theta_u-\theta_l}}$	$\frac{\theta_u}{\theta_u-\theta_l}\frac{7}{24}$
D_2	1	$\frac{1}{\Delta\theta}\left(\theta_u-\frac{p_2^{CM}-p_1^{CM}}{s_2-s_1}\right)$	$\frac{1}{2}+\frac{\sqrt{\theta_l}}{2\sqrt{\theta_u-\theta_l}}$	$\frac{\theta_u}{\theta_u-\theta_l}\frac{7}{12}$

In equilibrium, the resulting demands are shown in Table 4.4. Thus, in a covered market demand for high quality is always greater than demand for low quality:

$$\frac{D_2^{CM}}{D_1^{CM}}=\frac{2\Delta\theta}{\theta_u-2\theta_l}>1 \quad \text{for} \quad \frac{\theta_u}{\theta_l}\in(2,5)$$

The same holds true for the just-covered market where the corresponding equation in Table 4.4 obviously shows that firm 2 has a market share of more than 0.5 as the second term is positive by definition leading to the reverse result for firm 1. Finally, in an uncovered environment, the equations show that the high quality firm has a market share twice as large as its competitor. These explanations are illustrated in Figure 4.3 where the blue line shows demand of firm 1 and the orange line the corresponding demand for firm 2. Total demand is shown by the gray line.

For firm 2, profits exceed those of firm 1 under each market configuration. However, as preference for quality widens among consumers, profits decrease. At this point, it might be helpful to emphasise the assumption that the mass of consumers remains constant during the analysis. That means, firm 2 caters to all consumers under a monopoly configuration[156] (low value of $\frac{\theta_u}{\theta_l}$) and gradually loses demand as firm 1 enters in a covered market as it is shown in Figure 4.3. Once the market is uncovered, the mass of consumers is divided into three groups:

- Consumers who do not participate in trade.
- A few consumers buying from firm 1.

[156] Note that despite slightly different assumptions between the present models and the one by Shaked and Sutton (1982) a too intense price competition among firms drives one firm out of the market at all.

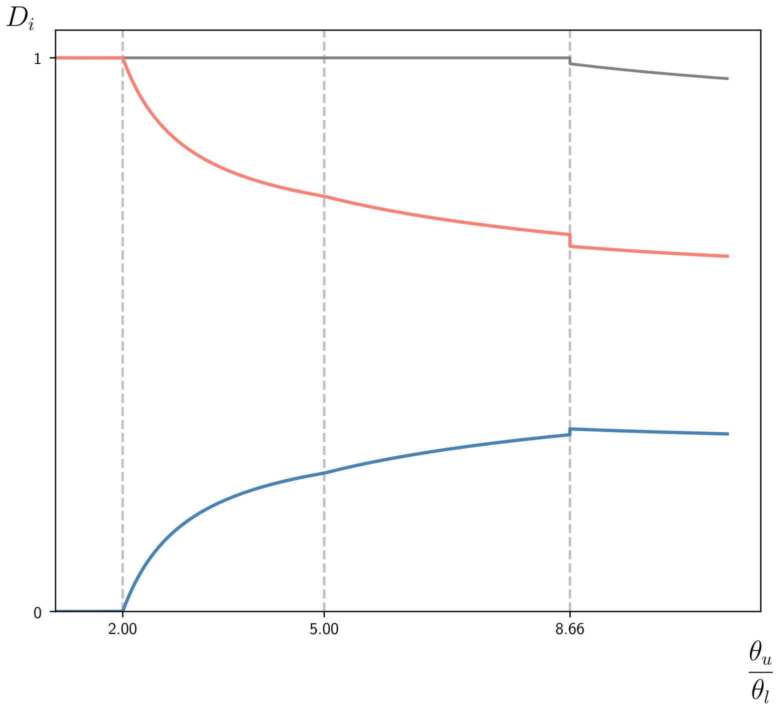


Figure 4.3: Demands in vertically differentiated markets

- The remaining consumers buying from the high quality firm.

The jump in demands at the threshold between the just-covered and the covered market is due to the breach in the rationale. This means, firm 1 manages to (just-)cover the market until it is no longer profitable to do so. Less intuitive at this point is the fact that market share of the low quality firm increases at the transition from a just-covered to a covered market. The concomitant drop in prices and quality explains the resulting higher demand for firm 1. However, it must be noted that a decreasing quality restrains some consumers from consumption at all leading to an uncovered market. At the same time, consumers that were previously buying from firm 2 decide to switch to the low quality alternative as the quality-price ratio happens to lead to a higher surplus. Consequently, the high quality firm's demand plummets at the transition.[157] With regards to profits, firm 2 cannot compensate the reduced demand by the higher prices charged and in comparison to the optimal

[157] It must be noted that, simultaneously, (the profit maximising) firm 2 decides to increase its price. Thus, both firms implicitly contribute to the decrease in demand.

price under a just-covered market (right below the threshold) profits are lower under a covered market.

To conclude the general analysis of vertical differentiation it remains to be noted that for either firm the characteristics of consumers are no decision variable. Therefore, it makes no sense to optimise with regard to $\frac{\theta_u}{\theta_l}$. But instead, the analyses to Wauthy's model show that heterogeneity among consumers is the pivotal determinant for the four possible market outcomes. Similar to the intermediation model by Gehrig (1993) in Chapter 3, the portion of consumers who refrain from purchase increases (after the threshold between the just-covered and uncovered market in terms of the fraction of the distribution's boundaries is exceeded) as heterogeneity rises.[158]

Beyond the issue that the distribution of consumers is usually externally given further limitations of the analyses have to be stressed: the remarks given were centered on the demand and quality rationales of the two firms. However, the assumptions that determining some quality level is costless is most certainly too simplistic. To extend the model, cost of quality needs to be assumed. Thereby, a rationale for an optimal level quality can be derived. Considering increasing marginal costs of quality, quadratic cost functions (in terms of the quality level s) are a parsimonious and established way.[159] In the model on platforms with vertical differentiation below,[160] this disadvantage is remedied and costs of quality are incorporated in terms of research and development costs.

4.3 Network effects

Another sphere of non-price competition are network effects. With the increased connectedness of individuals through mobile internet, platform-based business models have become popular. Research on these business models builds upon these

[158] Note that in Gehrig's (1993) case consumers or buyers refrain from an monopoly intermediation service and explicitly have the possibility to trade in a search market.

[159] Cf. textbook examples in (Woeckener, 2014b, pp. 176–192), Tirole (1988, pp. 296–298), Belleflamme and Peitz (2015, pp. 120–126).

[160] Cf. Chapter 6.

network effects. The beginning of this research branch marks the seminal publication by Rohlfs (1974). He analyses the market for telecommunication services and emphasises that "[t]he utility [...] a subscriber derives from a communications service increases as others join the system."[161] These network effects can be described as interdependent demand, i.e. demand rises (or more generally it may also fall) with the number of agents using a service or good leading to economies of scale in demand.[162]

The standard example on network effects are telephone networks. Imagine, a consumer is the only person having a telephone. The phone would be useless as there is nobody else to call. If, however, all of the consumer's friends had a phone as well, it makes sense to have one, as now the possibility to call someone or to be called is established. The demand externality says that the more consumers are connected, the higher the benefits for affiliated consumers.

It is notewothy that the literature on these effects and their implications surged during the 1980s. This rise in interest cannot only be explained by technological progress in telecommunication as telephones were developed in the 19th century and as the market for telephones was well established by the time. Much more the approach on dependencies in consumption made the topic interesting to researchers.

Contrary to simple network markets, where network participants influence each other, platforms are characterised by network effects that affect agents of different groups. To illustrate the general setup of a platform and to distinguish different types of network effects, Figures 4.4 and 4.5 show in a simplified way how interdependence can be understood in both settings. On the top, there is a set of users A that are affiliated to a network where each user (dots) is connected to others. As the number of users N increases, all users of A benefit and obtain a larger utility. For the utility u of an individual $i \in A$ follows $\frac{\partial u_i(N)}{\partial N} > 0$. That means, with positive network effects user's utility increases as the network expands. Since these agents are of the same group, they *directly* affect each other. Therefore, these are termed direct network effects.

[161] Rohlfs (1974, p. 16).
[162] See Katz and Shapiro (1985, p. 425).

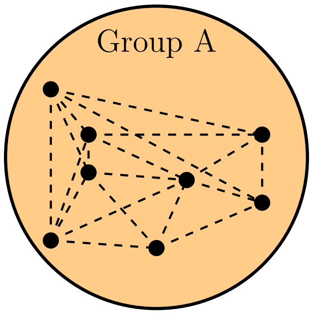


Figure 4.4: Direct network effects

A standard approach to determine a network's value is to apply *Metcalfe's law*.[163] It states that the value a network creates for a user is proportional to the number of users connected to the network. As that effect applies to all users, the value by numbers can be written as $N(N-1)$ where N denotes the number of users, as before. Therefore, the value increases almost quadratically as the network grows.[164] Indeed, this many-to-many network structure will not fit to all networks. Broadcasting networks, for example, do not fit into this many-to-many setup. Instead, only one member is connected to the remaining members. In that case, the network's value is linear with respect to its user base. Sometimes this is referred to as *Sarnoff's law*.[165] For networks of interlinked groups, the effect of growing user bases is exponentially increasing. This relationship is termed *Reed's law*.[166] Examples for this latter kind of network are chat systems or social networks.[167]

The examples on *Sarnoff's law and Reed's law* illustrate the fact that a network is affected or even governed by subjects on different levels (a broadcaster or an administrator). However, this dependence is not limited to solitary institutions, but can encompass other networks or groups. Figure 4.5 illustrates such a *platform*. In the graph, there are two groups A and B containing a number N_A and N_B of agents, each. Both groups are connected through an intermediary — the platform.

[163] Robert M. Metcalfe is a pioneer in internet technology and was involved in the development of Ethernet.
[164] See Shapiro and Varian (1999, p. 184).
[165] David Sarnoff was an American pioneer in radio and television.
[166] In reference to the American computer scientist David P. Reed.
[167] See Peters (2010, pp. 39–42) and Clement and Schreiber (2016, pp. 66–70).

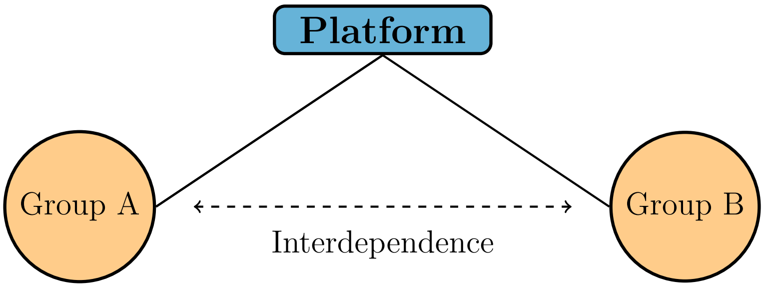


Figure 4.5: Indirect network effects

The agents of either group benefit from the presence (on the platform) of more users in the other group, i.e. $\frac{\partial u_i^A(N_B)}{\partial N_B} > 0$. This formulation gives the positive cross-group externality. These externalities are coined indirect network effects as the opposing group exercises these externalities.[168]

In general, a platform can contain more than two-sides, i.e. more than two user groups. The effects between sides can both be positive and negative. Obviously, the effects between groups can be one-sided, i.e. only one group benefits from the other, but not vice versa. And in platform settings, where at least two distinct groups are affiliated to an intermediary, network effects can also occur within a user group as in Figure 4.4. This means, both direct and indirect effects can occur at the same time.

As indicated above, network effects are not limited to positive externalities. Marginal utility $\frac{\partial u_i^k(N_l)}{\partial N_l} < 0$ with $k, l \in A, B$ are viable, too. Reasons lie in increased competition, nuisance, overload or vanity of members.[169] Figure 4.6 summarises the dimensions of network effects along succinct examples.

In the following sections pivotal publications on network effects are briefly recapitulated to give a compact literature review. Along this overview, definitions of keywords from the platform realm are assessed and their relevance within a mobility intermediation market is accentuated.

[168] These term are not unanimously defined. Parker and Van Alstyne (2005) for instance use the terms intra- and intermarket network externalities for direct and indirect network externalities, respectively.

[169] See e.g. Chapter 10 in Shy (2001) or Peters (2010, p. 34) in a one-sided context or Chapter 12 in Evans and Schmalensee (2016) and Organisation for Economic Co-operation and Development (OECD) (2009, p. 98) in a multi-sided context.

	Positive	Negative
Direct	Telephone Online Video Games	Excessive Information Competition
Indirect	Credit Cards Application Stores	Excessive Advertising

Figure 4.6: Dimensions of network effects

Own representation based on Parker et al. (2016, pp. 29–32).

4.3.1 Compatibility

In the introduction to this chapter, network effects were described as demand interdependencies among consumers. The importance of this topic becomes clear in connection with competition of different networks. In telecommunication different (physical) providers of the necessary infrastructure can restrict access of their network to others. Back in the 20th century this was still a topic for telephone companies as calling a member of a different network involved differentiated pricing patterns. Today, this problem still exists in international calls (using the telephone infrastructure instead of IP connections).

In contrast, some modern communication networks have explicitly decided to stay incompatible with their competitors. This includes, for example, social media such as *Skype* or *Whatsapp*. These examples are closely related to the telephone case as they both offer calls (and messages). However, neither of them is compatible to each other or to traditional telephone networks (including to SMS).

Katz and Shapiro (1985) offer a model where consumers are homogeneous toward valuation of the network effect that is associated with the product of a firm. Depending on the decisions firms make on compatibility of their product to a competitor's product, the network of a product can encompass the network by the product of a rival. These compatibility decisions can include bidirectional or only unidirectional compatibility (requiring for instance an adapter). For firms compatibility is, however, a double-edged sword. On the one hand, offering a compatible product leads to greater network for consumers who value the network's size. Therefore, the product becomes more attractive to consumers and sales increase. This is shown by the authors, given full compatibility of the networks (products). But on the other hand, competition intensifies as products are less differentiated with respect to their network sizes leading to perfectly competitive equilibrium with prices at marginal cost.

The question on how to overcome an established base, i.e. an existing network in favor to a new (incompatible) standard, is discussed in Farrell and Saloner (1985). In their model consumers are differentiated with respect to their information on an established and a new standard (network). As a new technologically superior standard lacks users (and compatible peripheries), consumers refrain form switching. Farrell and Saloner (1985, 1986) speak in this context of excess inertia and the *penguin effect*. I.e. nobody wants to hop into the cold water first and switch to a new network.[170] Once the inertia is overcome, the network effects tip over towards the new standard where others quickly follow leaving the old one and starting a bandwagon effect as network effect of the extant standard comparatively decrease.

4.3.2 Lock-in and switching costs

As the discussion of excess inertia demonstrates, the behaviour of others affects the decision made by agents. This is a central aspect of (network) externalities. In multi-period analyses consumers affiliated to a product or network will base their decisions on former purchases. In case of commuters who have subscriptions for the services of a transport provider (or even an association or union), their choices of which transport system to use (for commuting) is based on their existing ticket. The conflict of switching costs appears when transport services of competing firms offer a better option to make the trip. Now, the traveller faces the trade-off to buy a full

[170] The authors also discuss the case, where a new standard is acquired, despite some users are not convinced of the superiority of the new standard. This behaviour is termed excess momentum. See Farrell and Saloner (1985, pp. 79–81).

priced ticket for the ride with the service he has no existing contractual relationship or to accept the disadvantage resulting form a ride with his subscription.[171]

Generally, Farrell and Klemperer (2007, p. 1977) define switching costs as the cost the consumer faces "when an investment specific to his current seller must be duplicated for a new seller." These costs offer an approach to explain why, despite lower prices, consumers baulk at changing their supplier or network. Consequently, multiple networks can coexist. Shy (2001, pp. 188–196) illustrates this by a simple model of competition for private bank accounts. In this case, switching costs emanate from existing links to the locked-in account, such as paychecks, references to investment accounts or standing orders and direct debit.

An additional reason lies in signaling by borrowers. This means lenders have to give up their probably good payment history on loans that can lead to favorable credit terms on new loans. A new bank cannot access the previous behaviour and will make credit decisions on fewer information resulting in less favourable terms.[172]

Shapiro and Varian (1999, pp. 131–133) summarise the lock-in process as a cycle. Once a brand is selected, the consumer is motivated to apply the product (the authors speak of sampling). After that, consumers get accustomed to the product and create preferences for the good building an entrenchment which finally results in lock-in. The cycle restarts once the consumer considers a new brand, but refrains

[171] The choice to be made by a traveller is to weigh the benefits in terms of surplus of both options. Let

$$r_1 = V - p_1 - c_1$$
$$r_2 = V - p_2 - c_2$$

where r_1 and r_2 are the surpluses obtained by either option. Assuming index 1 describes the service of the firm where a subscription is at hand. Here, the surplus is given by the benefit value V of having travelled to the destination minus the ticket price and the non-pecuniary cost incurred due to this option. That is, value of time or the value of discomfort due to frequent switching. The ticket price p_1 is assumed to be lower than p_2 of the alternative. This may include rebates on tickets due to the subscription or the price may be zero in case of a flat-rate. In contrast, the cost of the alternative c_2 are assumed to be lower than c_1 such that the subscription leads to loyalty, despite there exists a faster or more suitable alternative. By the same argument, the traveller could revoke his subscription and switch entirely to the alternative service. Given the subscription's substitution, the argument is reminiscent of Von Weizsäcker (1984).

[172] Thus, switching users send a signal of minor solvency leading to the famous mechanisms described in Akerlof (1970).

from switching or, if switching costs are lower than the net benefits of the new product, a shift will be performed as the lock-in situation has ceased to work. Now, the cycle turns for the new product to establish lock-in.

However, the question of where the circle starts remains. This problem goes beyond one-sided network effects and is central in platform economics as well. Due to the analogy to the question of whether chickens or eggs came first, research on entry strategies and on building platforms is associated to the chicken and egg dilemma.[173] This matter will be pursued next in the discussion on platforms and indirect network effects in the following chapter.

[173] Research on this quandary using Granger causality yielded as an answer that the egg came actually first. See Thurman and Fisher (1988).

5 Platform business models

In this chapter the discussions on intermediation and on network effects in the previous chapters are picked up and are extended by a literature review on intermediated markets that are driven by indirect network effects. In comparison to both theory on intermediation and network effects, the literature on platforms was just developed in the early 2000s and is due to the rise of internet-based commerce of great interest to economists.

5.1 Platform development

5.1.1 Entering a two-sided market

The publication by Caillaud and Jullien (2003) was among the first that performed the transition from a one-sided view on network effects to to indirect network effects. These externalities affect agents of a different user group.[174] From a network externalities point of view, a new platform is unattractive to both sellers and consumers as neither can harness any indirect network externality while the opposite side is absent. The question is, thus, who will be first on a platform — sellers or consumers? As with lock-in cycles, this challenge is reminiscent of the chicken and egg problem discussed at the end of the preceding chapter. The authors take this position as their starting point to analyse duopoly competition between two platforms and emphasise on entry scenarios.

In a first setup platforms offer exclusive services to their members. This means, the established networks are disjoint groups. Given the same cost structure of both

[174] In case of sharing platforms, the user groups may not be disjoint. However, considering the motivation of a single interaction, the groups can be redefined to be disjoint.

platforms, an incumbent firm benefits from positive beliefs with regards to the allocation of members. This concentration leads to a dominant-firm equilibrium where only one platform is active.

An entrant, on the contrary, has to challenge the bad expectations towards his networks. Therefore, he has to apply a *divide-and-conquer* strategy. This strategy involves subsidising one market side to get those users on board while recouping the associated expenses on the side. I.e. one group is divided and so to speak lured to the entrant while the other side wants to access this group in order to make transactions with it. As under this strategy, the first group is affiliated with the entering platform, the other is forced to join the entrant and is thereby conquered.

From a strategic point of view, three points follow and need to be considered when applying a divide-and-conquer strategy. These are a) the price elasticities of the groups, b) the relative strength of the indirect network effects and c) competition from other platforms.[175] The first point is straight forward as it is simpler to convince price sensitive subjects, i.e. the group with higher price elasticities to join a favourable platform with relatively low prices. The second point focusses on the valuation of the counter party and on the fact that these cross-valuations can differ between the groups. Therefore, the side that benefits most from the opposing side is willing to accept a higher price. Consequently, this side has to be conquered. At last, surrogates and competitors play a role when choosing whom to subsidise. The rationale is to divide the group that is exposed to competitors or is supplied with substitutes on that market side.

Returning to the entry problem by Caillaud and Jullien, an incumbent can also apply a divide-and-conquer strategy to deter entry. However, their model concludes that the threat of entry leads to competitive pricing involving zero profits for both firms (while one is inactive).

The authors extent these thoughts by relaxing the exclusivity constraint. Thus, members are no longer constrained to be affiliated with a single platform, but can instead choose to be active on multiple platforms at a time. This behaviour is coined multi-homing, in contrast to single-homing where users are only present

[175] See OECD (2009, p. 164).

on one platform.[176] Given this possibility, a division of consumers is not enough for a divide-and-conquer strategy by the entrant to be successful. The reason is that the acquired users are multi-homing and may have the choice to decide on which platform the transaction takes place if the match occurs on both platforms. Rationally, it is the one with lower transaction fees.[177] As a first result, three market configurations follow given entry.

- The entrant is a second source (users multi-home, but perform transactions whenever possible on the incumbent's platform).

- The entrant is a first source (users multi-home and perform transactions whenever possible on the entrant's platform).

- The entrant is a sole source (users single-home with the entrant).

Caillaud and Jullien (2003) determine conditions under which circumstances the respective case applies. Given global multi-homing, meaning all parties multi-home, there exists a pure equilibrium. Here, the entrant charges a low membership fee (possibly a subsidy) and in comparison to the incumbent higher transaction fees. In sequence, all transactions with a match on the incumbent's platform are performed there. While only those transactions, where no match occurred on the incumbent's platform, but with a match on the entrant's platform, are carried out on the latter one.

To deter entry, the incumbent will charge zero transaction fees. This resembles a dominant-firm equilibrium and the second market configuration described above will not be attained.

Given partial multi-homing there exist mixed equilibria. These depend on the matching technology and the costs of the platforms. For an equilibrium to exist,

[176] In the model of Caillaud and Jullien (2003) both parties can benefit from bilateral multi-homing as matching is not solely determined by presence of two members of either group on the platform, but depends on the matching quality the platform offers. Thus, bilateral multi-homing can ensure the presence of both parties on both platforms and thereby raising the probability of a successful match.

[177] Beyond that, the conquered side that is used to recoup the losses of the subsidy has limited incentives to get affiliated with the entrant.

the matching technology needs to be good, such that the probability of a successful match is close to one and costs are significantly different form zero. Under these conditions, there exists an equilibrium where both firms earn positive profits by charging positive registration fees. This equilibrium can fail when one firm tries to divide both sides by charging slightly negative registration fees and tries to recoup the associated losses by positive transaction fees. Thereby, the entrant can undercut his competitor overcoming the bad expectations by both groups. However, subsidies cannot be fully recouped leading to at most a zero profit. Despite being an equilibrium, neither firm has an incentive to apply this last strategy.

For an incumbent platform, this redounds to the question whether the technological advantage in terms of matching quality or, more precisely, matching probability is high enough to deter entry to his exclusive network or whether to allow entry and open the network? The latter case will preclude the entrant form overtaking the market and can yield a global multi-homing equilibrium.[178]

Looking at market for mobile ticketing in personal transport, there are several examples where new technologies struggled to overcome the chicken and egg problem. Among these are *Teltix* and *Touch&Travel*-System by DB, which have been briefly described in the course of Chapter 2 above and which are both discussed in more detail in Appendix B below.

5.1.2 Dynamic strategies

Another view on two-sided markets is offered by Weyl (2010). He analyses the behaviour of platforms in dynamic settings. In this context, he advances the idea of a *divide and conquer* strategy. This means, a platform has ample incentives to charge low prices at market entry (possibly to both market sides) as to ensure participation independent of growth on the other side.[179] Due to the achieved independence of participation, this group is insulated from the exact level of users on the other side. Weyl coined this strategy an *insulating tariff*.[180]

[178]See Caillaud and Jullien (2003, pp. 315–322).
[179]However, some participation on the other side is required.
[180]See Weyl (2010, pp. 1647–1649).

When platforms maximise their profits, standard marginal revenue to marginal cost relationships follow. In the two-sided setting of Weyl (2010), marginal revenues contain a term for the additional revenue generated on the other market side by an additional user. However, assuming that users differ in their valuation of the network externality the platform can only internalise the cross-market effect generated by this marginal user's valuation. Consequently, the prices charged reflect only the characteristics of the marginal user. This relates back to the discussion of quality aspects in monopoly pricing and leads to the conclusion that a platform only partly internalises the network effects.[181]

5.2 Competitive bottlenecks

Armstrong (2006) takes up the discussion of multi-homing users on platforms. Similarly to the paper by Caillaud and Jullien (2003), this publication is numbered among the pivotal literature on two-sided markets. In contrast to Caillaud and Jullien, Armstrong takes a platform that is not threatened by entry as a starting point. The surplus of platform users is the benefit of the other groups presence on the platform reduced by the intermediary's price charged. Assuming positive network effects, he shows that monopoly pricing leads to Lerner formulas on both sides. However, the distinctions are the respective network externalities that are generated by the opposing group. As above, the more elastic market side gets a discount on group inherent costs while the other side is charged a premium in comparison to standard monopoly pricing. Given high elasticities for the first group and a high valuation of the network benefit by the second, profit maximising pricing can include zero or even negative prices for the first group. The example used by Armstrong is yellow page directories, but other information services that are financed by ads fit into this scheme as well.[182].

[181] See Weyl (2010, pp. 1651–1653) and cf. Spence (1975). This line of though of the *Spence* distortion is extensively discussed in further papers by the author himself (e.g. White and Weyl (2016) or Veiga, Weyl, and White (2017)), but also critically assessed by Tan and Wright (2018) (cf. in this context Weyl (2018)).

[182] See Armstrong (2006, pp. 671–673).

In a second stage, Armstrong introduces competition. Therefore, two platforms compete in prices for both groups to join their service. To simplify the analysis, he assumes external differentiation of both platforms. Thus, for both groups the platforms are located at terminal points of a *Hotelling* line. The group members are uniformly distributed between these points. This implies exogenous demand[183] and given that the valuation of the network externality is lower than transport costs in (relatively) a market-sharing equilibrium with both platforms active follows.[184]

Armstrong shows that there only exists a symmetric market sharing equilibrium where both platforms charge similar prices. These prices consist of three parts:

- Group inherent cost.
- Transport cost as a factor of market power.
- Network effects.

Depending on the profit generated by an additional user on the opposite side, the network externality will either reduce the price on that market side (given this additional profit is positive) or the price exceeds costs and transport costs (when the opposing side is subsidised by the platforms).[185] Ultimately, both platform make a positive profit while their overall market power (due to transport cost) is reduced by the valuations of the network effects.

Given the single-homing framework, Armstrong (2006) analyses the cases where platforms can opt between different schemes to charge their users. In a first case, platforms can only charge one price for both groups. This happens when they cannot (or must not)[186] discriminate between user groups. As a result, the equilibrium prices meet in between the prices where discrimination is allowed.[187] Therefore, one group has to pay a lower price while the others are charged more.

[183] The case of local monopolies due to high transport costs has been omitted.

[184] Formally, this follows from the second order (determinant) condition of the Hessian in the maximisation problem.

[185] Note, that the assumptions on the valuation of the externality and transport costs yield a solution where prices on both market sides are curtailed by the opposite side's valuation of the network effect. Thus, the network effects diminish platform profits as competition for market share intensifies. See Armstrong (2006, p. 675).

[186] Possibly due to legal restrictions, such as laws against discrimination.

[187] Assuming at least some degree of heterogeneity in both groups.

In a contrasting setting, prices can consist of up to two elements. Such prices are called *two-part tariffs* and can include a fixed price (as before) and a marginal price depending on the number of users on the other side.[188] A system like this allows in the extreme cases for both a fixed price only or a price that depends only on the number of users on the other side, i.e. the marginal price.[189] The author shows that a continuum of symmetric equilibria exist depending on the degree of how these variable prices are applied. However, he struggles to identify the equilibrium to which the parties coordinate on. Nevertheless, Armstrong identifies these marginal prices as a way to increase platform profit. As marginal prices help to internalise the network externalities, these are an instrument to soften competition for users by platforms.[190]

Finally, Armstrong addresses the option of multi-homing. However, only market constellations where one side is multi-homing are considered. The argument against global multi-homing lies in the fact that any member of platform has no incentive to join another one, given the opposite group is already present on both platforms of the same set.[191] Applied to transport intermediaries, a traveller might be affiliated with a transport platform that includes all transport firms and thus represents all transport possibilities. In that case, the traveller will receive at most a non-positive marginal surplus from joining an additional intermediary as the supply offered cannot be greater than on the already committed platform.[192]

Armstrong termed asymmetric multi-homing market configurations with one side single-homing and the other one multi-homing as *competitive bottlenecks*. The meaning of this will shortly become clear. Let the first group consist of single-homing travellers and assume that transport firms on the other market side all multi-home. Then the number of transport firms joining a platform depends on

[188] Cf. Rochet and Tirole (2006) for an analysis of both extreme pricing cases.

[189] For a more detailed discussion on marginal pricing confer to the discussion on Rochet and Tirole (2003) below.

[190] See Armstrong (2006, pp. 673–677).

[191] See Armstrong (2006, p. 669). It can also be noted that global multi-homing can lead to inefficient market outcomes as Hermalin and Katz (2006) show. In their article on network providers they show that two groups who are both affiliated to two networks may pay a premium for the right to choose the network where a transaction takes place.

[192] Considering membership fees, the marginal surplus will be negative.

the number of group one users and the price charged.[193] In an equilibrium Armstrong assumes travellers' surplus to be constant. As travellers surplus depends on the number of transport firms, too, the price for travellers can be taken implicitly in terms of the constant surplus. Consequently, the profit function is reduced to a function of the number of transport firms, only. The first order conditions then give surplus of both travellers and the intermediary in terms of the number of transport firms associated with the same platform. In this formulation surplus of transport firms plays no role in platforms' profit maximisation rationale. This also becomes clear when looking at the gross surplus transport firms generate on a platform. Here, marginal surplus (with respect to the number of transport firms) equals exactly the price charged to the very group.

Substituting transport firms' revenue by the formulation of transport firms' gross surplus into the profit maximising term above, total surplus can be maximised. As a result, Armstrong shows that the number of attracted multi-homing transport firms becomes larger as this group's interests are taken into consideration as well.

Beyond that, his comparison between profit and surplus maximisation shows that a platform is handed market power on the multi-homing side which is leveraged by the other sides participation when platform acts as a profit maximiser. This means, a platform can control access to its single-homing users and can charge a premium form multi-homers. At the same time, competition arises for single-homing travellers as platforms require these users to attract the multi-homing side at all. This constitutes the *competitive bottleneck*.[194]

As before, Armstrong (2006, pp. 681–683) addresses alternative pricing schemes. The results, in general, match those of the single-homing scenario. In detail, the author looks at two ways to charge multi-homing agents. Either, prices depend on the number of single-homing travellers present on the platform or the intermediary charges a lump-sum price. In the first case, transport firms join when their

[193] Where the derivatives are positive for the number of travellers and negative for the prices, respectively.

[194] To achieve this result the author assumed that there are only indirect network effects between parties. However, once there are direct (negative) externalities the result no longer holds. See Armstrong (2006, pp. 677–680).

Table 5.1: Price effects of multi-homing price schemes in competitive bottleneck markets

Network Effect	Lump-Sum Price Scheme		Network Adjusted Price Scheme
Positive	p_{sh}	$<$	p_{sh}
Negative	p_{sh}	$>$	p_{sh}

profit from interaction with travellers, i.e. their valuation of the network effect (per traveller) exceeds the price (per traveller) charged by the platform. Given the Hotelling setup, travellers' prices are subsidised by the platform's revenues generated by transport firms.

A lump-sum charge increases competition for the single-homing side as lower prices attract more travellers and consequently also more transport firms. Ultimately, the optimal (equilibrium) prices take the prices of the first case as the first terms and amend these by a discount or premium depending on the actual direction of the single-homing side's network effect. Table 5.1 lists the results.[195]

Empirically, this model has been applied in a wider context to the transport sector. Molenda and Sieg (2018) consider a competitive bottleneck market for German shopping malls and their parking lots. These malls offer retail space to shops (who multi-home in different shopping malls) and they offer parking space to consumer. Key results are that most German malls in suburbia offer free parking as the network externality they produce to shops is large. In consequence, retailers have to subsidise consumers while the platform partly internalises this externality from consumers to suppliers. Contrasting this result, malls in central areas often do not offer free parking space as they cannot internalise the externality. This can be explained by freeriding consumers who use the parking facilities, but shop outside the mall in the city center.

[195] The knife-edge case where single-homing agents do not care for the multi-homing side in terms of network effects has also been discussed by Gabszewicz, Laussel, and Sonnac (2001, p. 646). Note, their model ultimately extend the Hotelling solution with quadratic costs of d'Aspremont, Gabszewicz, and Thisse (1979) by a third stage. This yields a competitive result where firms locate at the center of the Hotelling line.

5.3 Price structure and two-sidedness

Rochet and Tirole (2003) and Rochet and Tirole (2006) mark further pivotal papers on two-sided markets. Central to their argument for two-sidedness of markets is the price structure in comparison to the price level instead of the mere presence of cross market network externalities. The question is, thus, not only how much platforms charge parties (in total), but who is charged (how much) and how a chosen price pattern affects the market outcome? As above, their analysis targets price systems where "one side [is treated] as a profit center and the other as a loss leader, or, at best, as financially neutral."[196]

Similarly to Armstrong (2006), their papers begin with a simplified monopoly setup where a platform caters to two market sides. However, Rochet and Tirole assume a per transaction prices instead of membership fees. Therefore, the rationale for users to use the platform lies in the comparison of their benefit (per transaction) and the price charged by the platform to the corresponding group. Given that the benefit of trade is independent of the opposing market side's size, there does not seem to be a network effect present.[197] Still, there is a network effect when looking at the overall surplus of a group as the authors assume that the number of transactions is simply the product of the demand functions[198] of the two groups. This, in sequence, implies that both users conduct transactions with all users on the other side — Indeed, this is a strong assumption that is hardly applicable to the market of transport intermediation[199] — As a result the authors show that standard monopoly pricing will prevail and that the ratio of elasticities determines prices as well as the price structure of who has to pay which amount to the intermediary.

[196] Rochet and Tirole (2003, p. 991).

[197] Even in cases such effects exist, a platform can easily internalise these effects by commensurate premia on prices.

[198] Rochet and Tirole (2003, pp. 995–996) call these "quasi-demand functions" to account for underlying implication of the network effect and, thus, the number of users instead of only a dependence on the price.

[199] Even the authors acknowledge this drawback. See Rochet and Tirole (2006, pp. 652–661). However, as these models mostly exclude repeated transactions this argument could be used as a rough approximation.

Especially interesting in this result is the fact that this structure considers the actual elasticities instead of inverse elasticities, only:

$$\frac{p_i}{\varepsilon_i} = \frac{p_j}{\varepsilon_j}$$

Where ε denotes these elasticities for the two groups i and j. Solving for either price yields:

$$p_i = \frac{\varepsilon_i}{\varepsilon_j} p_j$$

This means, the more elastic market side is proportionately charged more than the less elastic one.[200]

In an additional step Rochet and Tirole analyse the problem from a social viewpoint. Therefore, they assume that the intermediary makes zero profits as the sum of prices charged to both sides equals the costs associated with their transactions. Given this Ramsey formulation, the optimal price structure amends the formulation of the monopoly case by taking the average surplus a group creates into account. Consequently, not only the price to elasticity ratio determines the price structure, but the costs assigned to a group. As above, the authors state this result as:

$$\frac{p_i}{\varepsilon_i} r_i = \frac{p_j}{\varepsilon_j} r_j$$

Restating this formulation once again in terms of (either) price shed's light on the effect of the elasticities. Their impact can be offset or reinforced by the average surplus r:

$$p_i = \frac{\varepsilon_i}{\varepsilon_j} \frac{r_j}{r_i} p_j \tag{5.1}$$

If both the elasticity and average surplus of a group are greater than the respective value of the opposing group, the effect on prices remains undetermined as either effect can dominate. In a situation where one group has a higher elasticity, but a

[200] See Rochet and Tirole (2003, pp. 994–997).

lower average surplus or vice versa, the total effect on prices reinforces the effect of the monopoly situation. In conclusion, the price structure may even be more skewed in a Ramsey environment than under monopoly pricing depending on the average surplus.[201]

In the transport setting, a non-profit public entity (as a Ramsey planner) will charge travellers and transport firms according to their price elasticities and the average surplus obtained form either group. Assuming that travellers are more sensitive to price changes (for information and matching services) than transport firms. Then, the first fraction on the right of Equation (5.1) will be greater than one. Similarly, the average surplus is assumed to be lower for travellers than for transport firms.[202] Thus, the second fractions scales per transactions prices of transport firms up as well. Meaning passengers are charged more for the platform's services than transport firms.

Furthermore, Rochet and Tirole amend their analyses by demand anomalies. These include marquee buyers who make the platform more valuable for sellers. A for-profit platform will shift its price structure and internalises this effect by charging a premium on sellers. In the transport setting this view of buyers and sellers has to be reversed such that there exist marquee transport firms who attract travellers.

The opposite happens when buyers or at least some buyers are insensitive to price changes and are characterised by inelastic demand. Again, the economic intuition is proofed correct as this leads to higher prices for buyers. These low elasticity buyers can, for example, be referred to as an installed base or locked-in buyers.

At last, Rochet and Tirole discuss the same scenario as Armstrong (2006) where one group is multi-homing while the other remains a single-homing.[203] Evidently, the results are compatible and the multi-homing side will face higher prices as the number of multi-homing users increase.[204]

[201]See Rochet and Tirole (2003, pp. 997–998).

[202]This is an assumption by the jaundiced view that fewer transport firms are active than travellers and thereby their total surplus is divided by a smaller number yielding higher values in average surplus. However, this requires transport firms' surplus to be present at all.

[203]I.e. a competitive bottleneck situation as introduced above.

[204]See (Rochet and Tirole, 2003, pp. 1007–1010).

The pivotal idea of a two-sided market is, thus, according to the authors that the price structure determines volume of trade and not just the price level.[205] Therefore, the neutrality of taxes on the market outcome, i.e. that it does not matter who is charged a tax, as an instance, must be questioned in two-sided markets.[206]

In their subsequent paper the authors focus on that very issue. They question *Coase's theorem* which states that a *Pareto* efficient market outcome will occur even when externalities are present. The road to this result is bargaining between parties. For the theorem to work, three prerequisites are required. These are:

- Tradeable property rights.
- A lack of information asymmetries.
- The absence of transaction costs (or at least low transaction costs).[207]

Rochet and Tirole narrow the bargaining process of the theorem down to intermediation where only the price level is of importance. Consequently, they infer that by violating the *Coase theorem* in terms of non-neutral pricing where the price structure matters, two-sided markets can emerge.[208]

Beyond that, the authors establish a link between their earlier paper to Armstrong's where they amend their theory by pure membership fees. Consequently, their statements on transaction-based prices and non-neutrality of the price structure require adjustments to the extend that membership fees facilitate a two-sided market. Furthermore, an infinite number of solutions in the maximisation of transaction volume indicates one-sidedness (as only the total price level mattes). Put differently, a unique (or at least finite number of) solution(s) to the problem leads

[205] The term two-sided market is not only ambiguously applied or defined in the context of network effects, but, for example, in the intermediation literature the term is used for dealers who quote both bid and ask prices. Accordingly, dealers who only quote prices to seller or buyers establish a one-sided market. See Harris (2003, p. 280).

[206] See Rochet and Tirole (2003, p. 1018) and (Rochet and Tirole, 2006, p. 648).

[207] Cf. Coase (1960, pp. 88–94) for an illustrative example.

[208] Rochet and Tirole (2006, pp. 649–650) emphasise that failure of the *Coase theorem* by no means redounds to two-sidedness. As, for example, asymmetric information can lead to inefficient market outcomes as traders value the benefits of transactions differently. Such a situation will not result in a platform mediated market per se.

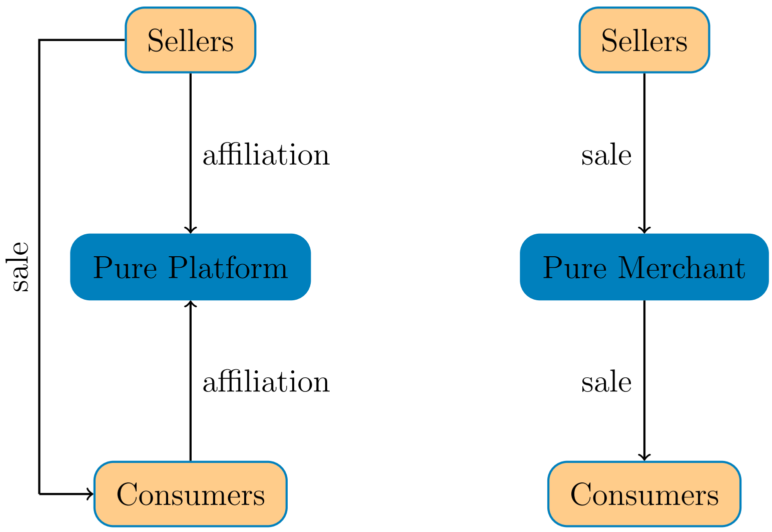


Figure 5.1: Platform vs. merchant

Own representation based on Hagiu (2007, p. 116).

to a two-sided interpretation, i.e. the price structure in this more general setup matters.[209]

5.4 Alternatives to platform business models

Based on these prominent contributions, OECD (2009, pp. 29–30) summarises three conditions for a business model to be considered two-sided. These are:

- There are at least two user groups that depend on each other.
- The size of a group has a positive impact on the value of the platform from the other user groups point of view, i.e. indirect network effect must exist.[210]
- The price structure has to be non-neutral.

[209] See Rochet and Tirole (2006, pp. 657–658).

[210] At this point OECD (2009, p. 29) is more restrictive than most publications. The organisation demands that "the value [...] *increases* with the number of customers on the other side." This is tantamount to requiring only positive indirect network effects. Nevertheless, this statement is in line with a majority of research as mostly positive externalities are considered including the model in Chapter 6 below.

Especially, the requirement of non-neutrality is widely challenged.[211] Among these is Hagiu (2007) who criticises this definition as "overly inclusive" as it "presumes a platform intermediating transactions between buyers and sellers without taking full control over buyer-seller transactions."[212] Hagiu, in contrast, breaks up the dichotomy between one-sided and two-sided businesses. His approach to platform markets emerges more from an intermediation point of view. Therefore, he analyses the difference between a merchant and a platform. As Figure 5.1 shows, Hagiu interprets a merchant as an institution that buys from one market side and resells goods or services to consumers on the other market side while platforms, on the other hand, only facilitate transactions and establish a matching technology both sides to meet.

Central to his analysis is that a platform demands less infrastructure and, consequently, requires lower costs in comparison to buying and reselling goods and services. However, given price distortions by for example complementarity, a merchant has full control over prices. Thereby, these distortions can be internalised by the reseller. Ultimately, the decision for either form of intermediation is governed by the power they have on prices and other strategic variables (bundling possibilities to stick with the example above) or to put it differently: who is taking the economic risk — intermediaries or sellers?[213]

In subsequent publications on multi-sided businesses Hagiu continues to emphasise the role of an intermediary to the two market sides. In Hagiu (2009), he analyses demand elasticities on platforms along product variety offered while in Hagiu and Spulber (2012), Hagiu and Wright (2015a) and Hagiu and Wright (2015b) the relationship between sellers and platforms are discussed from various angles. These include relationships between suppliers' products and the service of an intermedi-

[211] See for instance Gabszewicz and Wauthy (2014), Hagiu (2007), Osterwalder and Pigneur (2010) or Chowdhury and Martin (2017). Note, that quite many authors reference to the publications by Rochet and Tirole for a definition on two-sided markets, but fail to conceive their definition including non-neutrality. Instead the argument is reduced to indirect network effects which is viable, but not the intention of Rochet and Tirole. An example for this is just given by Chowdhury and Martin (2017).

[212] Hagiu (2007, p. 118).

[213] See Hagiu (2007, pp. 123–130) who lists more descriptive parameters that shift the decision to either intermediation mode.

ary as well as the question of vertically integrated structures which relates back to the discussion above. Hagiu and Wright (2015a, p. 164) note that a vertically integrated firm operates similar to a merchant: it retains all power while a platform shifts all related responsibilities to the sellers including design and other control variables of products and services. Thus, opening a business towards a platform business model allows for more competition on the supply side.

Nevertheless, the market power and its effects on the two sides of an intermediary remain open. Therefore, the next section gives a brief overview on antitrust approaches to platforms.

5.5 Antitrust implications

A major issue of two-sided business models is that traditional antitrust tools are inapplicable. This starts at the fundamental point of defining the market. A mere look at the prices and derived market power at one side of a platform gives skewed results. Consequently, tests of Small but Significant and Non-transitory Increase in Price (SSNIP) yield limited information. Similarly, evaluating price margins on marginal costs is often a dead end as most platforms largely depend on high investments that are independent of sales numbers and therefore fixed. Furthermore, the assessment of market shares generally does not include market shares on other market sides. Thus, the use of concentration indicators, such as Herfindahl-Hirschman Index (HHI), leads only to partial results that do not inform on the real market power.[214]

There are two ways how to deal with this problem. One is to analyse the overall impact on surplus. This redounds to justifying and accepting large market shares in these markets as ultimately the indirect effects generate enough surplus to outvalue price premia charged.[215] However, this approach struggles to yield policy implications as a surplus analysis could be vulnerable to discussions of what parts should

[214]See Evans (2003b, pp. 356–362) and Filistrucchi, Geradin, Van Damme, and Affeldt (2014).

[215]See e.g. Song (2013) for an empirical assessment or Nocke, Peitz, and Stahl (2007) for a theoretical work.

be taken into account. Consequently, the question of a proper market definition remains.

The second line of thought is to find appropriate measures on how to evaluate market power and its abuse or how standard procedures in market supervision can be applied. Farrell and Shapiro (2010), Alexandrov and Spulber (2013) and Alexandrov and Spulber (2017) offer ways to apply Upward Pricing Pressure (UPP) measures to analyse possible mergers and critical loss analyses on two sided markets.[216]

To sum up, measuring market power in two-sided markets remains an unsolved issue as traditional methods fail to apply easily. The approach of analysing total surplus struggles similarly to the UPP approach with the market definition.

5.6 A simple vertically differentiated platform model

The discussion in the previous subsections shows that differentiation marks a subtopic in the platform literature. And even there, most publications implement differentiation in a *Hotelling*-fashion. Thus, vertical differentiation takes a niche role within this branch as there are only few publications that consider this aspect.

In this section a version of the general vertical differentiation model from Chapter 4.2 is applied two-sided markets. Therefore, the simple model by Gabszewicz and Wauthy (2014) is presented and adjusted according to the results from above. Gabszewicz and Wauthy assume that network sizes on either side of a platform are recognised by the opposing sides as a measure for quality. The demands for both market sides follow for the uncovered market case according to Table 4.1 as:

$$D_{p,1} = \frac{1}{\Delta\theta}\frac{p_{p,2}\mathbb{E}[D_{t,1}] - p_{p,1}\mathbb{E}[D_{t,2}]}{\mathbb{E}[D_{t,1}]\left(\mathbb{E}[D_{t,2}] - \mathbb{E}[D_{t,1}]\right)} \qquad D_{p,2} = \frac{1}{\Delta\theta}\left(\theta_u - \frac{p_{p,2} - p_{p,1}}{\mathbb{E}[D_{t,2}] - \mathbb{E}[D_{t,1}]}\right)$$
$$D_{t,1} = \frac{1}{\Delta\alpha}\frac{p_{t,2}\mathbb{E}[D_{p,1}] - p_{t,1}\mathbb{E}[D_{p,2}]}{\mathbb{E}[D_{t,1}]\left(\mathbb{E}[D_{p,2}] - \mathbb{E}[D_{p,1}]\right)} \qquad D_{t,2} = \frac{1}{\Delta\alpha}\left(\alpha_u - \frac{p_{t,2} - p_{t,1}}{\mathbb{E}[D_{p,2}] - \mathbb{E}[D_{p,1}]}\right)$$

[216]See Farrell, Shapiro, et al. (2010) for an overview on upward pricing pressure and critical loss analysis.

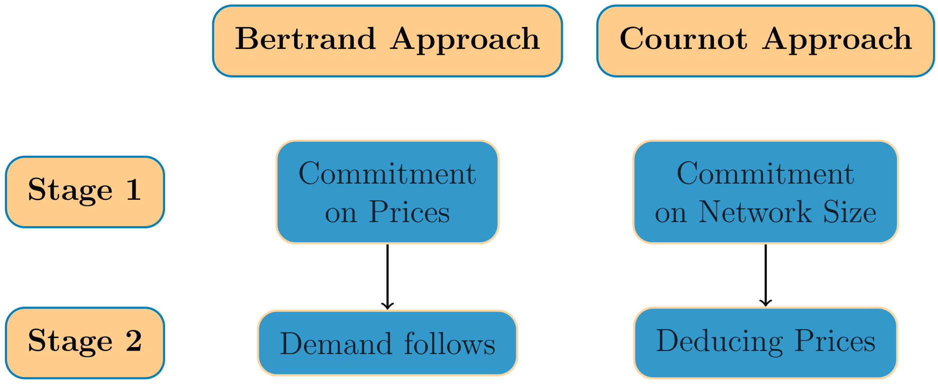


Figure 5.2: Platform game setup in Gabszewicz and Wauthy (2014)

The indices p and t refer to the two market sides.[217] These are amended by the two subscripts 1 and 2. They indicate the low and high quality platform, respectively. This means, platform 1 is denoted as the smaller one in terms of overall users. And α can, at this point, simply be interpreted, similarly to θ, as the characteristics of transport firms' heterogeneity.

In this duopoly setting, reduced demands are given by standard formulas:

$$D_{p,1} = \frac{\mathbb{E}[D_{t,2}]}{4\mathbb{E}[D_{t,2}] - \mathbb{E}[D_{t,1}]} \qquad D_{p,2} = \frac{\mathbb{E}[D_{t,2}]}{4\mathbb{E}[D_{t,2}] - \mathbb{E}[D_{t,1}]}$$
$$D_{t,1} = \frac{\mathbb{E}[D_{p,2}]}{4\mathbb{E}[D_{p,2}] - \mathbb{E}[D_{p,1}]} \qquad D_{t,2} = \frac{\mathbb{E}[D_{p,2}]}{4\mathbb{E}[D_{p,2}] - \mathbb{E}[D_{p,1}]}$$

Making the strong assumption of fulfilled expectations yields a Nash equilibrium with an uncovered market. Solving this system of equations yields symmetric market shares on both sides. These are $D_{p,1} = D_{t,1} = \frac{2}{7}$ and for the high quality platform $D_{p,2} = D_{t,2} = \frac{4}{7}$. Consequently, market shares are split two to one for the high quality firm.[218] Accordingly, prices on both market sides are four times as high for the high quality firm in comparison to the low quality firm. Namely, $p_{p,1} = p_{t,1} = \frac{2}{49}$ and $p_{p,2} = p_{t,2} = \frac{8}{49}$. These results comply with the prices defined in Equations (4.4) and (4.5) of the general model above.

[217] In a transport setting p stands for passengers, while t represents transport firms as the second side. See also Chapter 6 below.

[218] This is all in line to the general model described in Chapter 4.2 as the implied distribution characteristics (for both sides) are $\frac{\theta_u}{\theta_l} = \infty$ and $\frac{\alpha_u}{\alpha_l} = \infty$.

Table 5.2: Price and demand comparison in vertically differentiated platform markets

Solution	$p_{p,2} = p_{t,2}$	$p_{p,1} = p_{t,1}$	$D_{p,2} = D_{t,2}$	$D_{p,1} = D_{t,1}$	$\sum D_p = \sum D_t$
Bertrand	0.1633	0.0408	0.5714	0.2857	0.8571
Cournot (symmetric)	0.08	0.08	0.4	0.4	0.8
Cournot (asymmetric)	0.1726	0.0295	0.6357	0.2428	0.8786

In addition to this constrained result, Gabszewicz and Wauthy propose a different way in platform behaviour. This means, they alter the game played by two intermediaries. Instead of committing on prices, the authors suggest that platforms select network sizes first and that prices follow accordingly or more precisely are to be set in such a way that the selected network sizes are established. In Figure 5.2 these two ways to formulate the game played are illustrated. At last, the difference in committing on prices or on quantities leads back to distinction between Bertrand and Cournot competition.

In this Cournot game, the authors identify two valid equilibria. One where both coordinate on same network sizes and one where market shares are even more skewed than under the previous approach.

Specifically, demands are given in the fully symmetric case as $D_{p,i} = D_{p,j} = D_{t,i} = D_{t,j} = \frac{2}{5}$, with i and j as either platform. This implies prices to all sides of $p_{p,i} = p_{p,j} = p_{t,i} = p_{t,j} = \frac{2}{25}$, i.e. prices lie in between those of the Bertrand-approach game. Solving the equations for the asymmetric case yields a valid solution with demands at $D_{p,2} = D_{t,2} = \frac{1}{31}(13 + \sqrt{45})$ and $D_{p,1} = D_{t,1} = \frac{2}{31}(6 - \sqrt{45})$.[219]

In order to compare these numbers with the other solutions, Table 5.2 lists the results in decimal notation. The table shows that the symmetric Cournot approach leads to the smallest market coverage with 0.8. This result is due to the relatively high singular price charged. More interesting is the fact that committing on network sizes first leads to the highest market coverage. The explanation for this behaviour lies in prices of low quality firms. Here, the attained quality levels are lower than

[219] See Gabszewicz and Wauthy (2014, pp. 59–60).

in the Bertrand setting, but the discount in prices compensates this drawback. In sequence, this leads further users to use the platform's services.[220]

In practice, many platforms have skewed ratios between the number of users on either side. This leads to a major limitation of the model by Gabszewicz and Wauthy as they assume that users groups are fully symmetric. Furthermore, the shortcut by the assumption of fulfilled expectations largely simplifies the analysis. To overcome these drawbacks and to create a model for personal transport platforms this model is vastly altered and adjusted in the following chapter in order to fit to the characteristics of these two-sided markets.

[220]Cf. Figure 4.1c for an illustration. Note that the blue line has an absolutely lower intercept (price) and a smaller slope (quality level) in the Cournot case than in the Bertrand case. As the price discount outweighs the reduced quality cuts, the root lies at a smaller value or graphically speaking, further to the left.

6 Personal transport intermediation in a platform environment

6.1 Monopoly transport platform

As the evaluation in Chapter 2 has shown, there are transport associations catering their own service to customers via apps or browser-based solutions. Reasons for the decision of offering a closed platform, where only associated transport firms are marketed, are high investment costs for development of an alternative open MaaS solution. In addition, the lack of APIs for data of the transport firms involved hem the development of MaaS platforms.

Furthermore, political or regulatory motives may also impede the free market entry. An example of the regulatory constraints are exclusive sales channels. Licences or concessions to sell mobile tickets in public transport are only granted to a limited extend. The scope depends on the respective local government. To analyse markets with only one institution that matches transport firms and passengers the following, model is intended to shed light on the behaviour of the platform and its owners.

6.1.1 Framework

From the discussion on quality competition in Chapter 4, it is known that the characteristics of the assumed customer base and their corresponding distribution of quality valuations play a central role for the market outcome. Depending on the extend of heterogeneity among customers, the model presented in Chapter 4 shows that monopoly outcomes may be an endogenous result.

Transferring the framework of Chapter 4 to the realm of platforms raises the question, if similar results can be derived by accounting for differences in heterogeneity among two groups of customers catered by intermediaries? As the discussion on two-sided markets and the related literature in Chapter 5 show, assessments from a differentiation point of view are scarce, especially with regards to vertical differentiation. One additional example is Roger (2017) who shifted a basic vertical differentiation model to platforms including an external quality setting. Specifically, he assumes that consumers on both sides of a platform base their decisions on surplus functions à la Gabszewicz and Thisse (1979). To achieve two-sidedness (at least) one group takes the number of customers captured by the platform as the quality measure. The other group's quality measure is considered external and subject to increasing marginal costs of quality.

Following roughly the approach by Roger (2017), an intermediary platform has two customer groups who interact with each other. In Roger's case, the two groups are consumers of any kind and suppliers of advertisement (media and search platforms), health insurance or application developers. For simplicity, the two groups contain users that are heterogeneous with respect to a characteristic that is related to the intermediary's external quality provision and in the case of suppliers, the valuation of the other side's presence (indirect network effect) differs. However, the size of both groups is determined in Roger's model by two probability measures leading to a normalised demand on each side of exactly one. To account for size difference between the groups, Roger introduced a scaling parameter within suppliers' surplus functions.[221] To explicitly delimit demands, the probability measure will be replaced. Therefore, the assumptions on heterogeneity must be altered accordingly.

In addition, the parameter space Roger applies is opened up in the following analysis. This means, market coverage on both sides is no longer ex ante given as

[221] In Roger (2017, p. 196), this parameter is called e and scales the number of consumers affiliated to a platform.

it is assumed by Roger (2017). Thereby, the advantages with regard to demand modelling can be played out and endogenous platform participation by either user group may follow.

This marks the central aspect of the model below. It allows to identify market characteristics which lead to certain market outcomes and gives optimal choices for pricing and quality levels. In this manner, the analysis is alike to Wauthy (1996), however, transferred to the platform realm, including interdependence between the two market sides.

6.1.2 Assumptions

In the present model, the two sides of the market can be interpreted as travellers and transport service providers conducting actual rides for these travellers. Both groups decide on using the platform to offer services and book rides or to desist from using it depending on the benefit created. In the following paragraphs, these benefits and the corresponding surplus functions are discussed.

Travellers need information on how to get from one location to another. Depending on the frequency of travel, the information demand by travellers may differ. Daily commuters will, for example, surely know the alternatives on their rides. For rides to uncommon destinations, on the other hand, even a commuting subscriber to public transport is unaware of the alternatives. Similarly, other persons, who are unfamiliar to the transport system, demand information to decide on how to get from one place to another.[222] The task of the intermediary is, consequently, to provide such information. Generally, customers have different preferences on travel modes, but lower durations are generally preferred.[223] Thus, the choices given by the platform may decrease the time spent travelling. An integrated payment and information service for modes offered, further increases customer comfort and, ultimately, gross travel time can be reduced. This gross travel time includes the whole time associated with a ride: this includes time to obtain information and to

[222]Cf. Chapter 2 on how transport decisions are modelled in the traditional transport literature.

[223]Indeed, both travel modes and time valuation are interconnected. See e.g. Black (1981, p. 26), Abrantes and Wardman (2011) or Small (2012).

make decisions, to purchase a ticket, to get to a station or vehicle, to wait, time spent on the actual ride including stops as well as mode or vehicle change and, finally, time spent walking to the destination from the station. If the intermediary's task is viewed from a greater angle, the information paradigm must be extended. Travellers will value time savings achieved through the platform. Thus, the reduction of gross travel time represents the primary added value of an intermediary to travellers.

As the discussion on information and routing services in Chapter 2 showed, European law demands the provision of such services for public transport. These services are to some extend presently given away for free. Thus, a platform may struggle to redeem its expenses from travellers. The way to overcome this issue is integration. For one, integration with regards to transport services beyond public transport, but also vertical integration into other areas that affect gross travel time. Most importantly, a payment feature to pay for the whole ride represents a step to extract revenue from travellers. Furthermore, value is added when seamless intermodal transport is enabled. To accomplish this, the platform needs to create bundles and encourage transport firms and policy makers to provide transport hubs, where mode and vehicle change are feasible. In this way, the intermediary will generate travel data that can be used to increase coordination.

Getting back to heterogeneity among travellers, the integrated platform may offer reduced benefits to commuters. It can be safely assumed that they are familiar with the given transport possibilities. Thus, their valuation for the service might be limited.[224] However, even they can profit from the platform in case of unforeseen events such as delays of buses or blocked roads due to accidents. In such an event platforms can suggest viable alternatives and, therefore, cater to travellers' value of reliability.

[224]Viergutz and Brinkmann (2018) show that in contrast to first impressions, frequent commuters are indeed among those users of mobile information services. This gives reason that these services actually cater specifically to those users. However, their analysis also shows that passengers differ in their propensity to use mobile services. This ultimately supports the presented argument.

Beyond this, the value of time varies among travellers. Transport engineers often make the distinction between work-related and non-work-related rides or recreational traffic. The reason for this distinction is that travellers truly value time differently depending on the purpose of their ride. This fact is closely related to the time of the day at which travel occurs. This time of the day is used as an explanatory variable in former studies on value of time in transport. Additionally, differences in income have an effect on travellers' behaviour. Higher incomes lead to both longer distances travelled between workplace and residence and to a higher valuation of time. This results in a preference for faster modes. Nevertheless, researchers observe increasing travelling times with income and, thus, value of time.

Having mentioned the preference for rapid modes by high income individuals, a third attribute that is commonly used to estimate the value of time for rides represents the actual mode choice. Travellers on public transport, for example, elicit a lower value of time than individuals opting for individual motorised transport. All in all, the conjecture of heterogeneous valuation of time and reliability have been proven in numerous studies. However, research on the distribution of these characteristics is scarce and offers only limited insights.[225]

These considerations lead to the conclusion that the value created by an intermediary for travellers differs. To model this, travellers are assumed to be heterogeneous in their time valuation. This is incorporated into the following models by the valuation per time saved. The parameter for this is θ. Despite being simplistic θ is

[225] Cf. for a general discussion on value of time in transport to DeSerpa (1971) and Hensher (1977b). For estimated values used in German Federal Transport Investment Plan/Bundesverkehrswegeplan (BVWP) see Axhausen, Ehreke, Glemser, Hess, Jödden, Nagel, Sauer, and Weis (2014, pp. 138–150) or Abrantes and Wardman (2011) for values from the UK. Additionally, Small (2012) offers insights on state of the art methods and problems with regards to heterogeneity among travellers.

assumed to be uniformly distributed. In the analysis below this reduces complexity while providing rationales for decision making. Formally, θ is defined as:[226]

$$\theta \sim U(\theta_l, \theta_u) \text{ with density } \frac{\kappa_\theta}{\theta_u - \theta_l} \tag{6.1}$$

Where θ_l and θ_u are the lower bound and upper bound of the distribution, respectively. By definition $\theta_l < \theta_u$ and $\theta_l \geq 0$. κ_θ is simply the mass of the distribution allowing to calibrate the model and especially to account for differences in size between the two market sides catered by the platform. That means, a mobility intermediary will have more customers on the passenger market side than transport firms associated with it as shown by the tables in Chapter 2.2. Thus, κ_θ will generally be larger than the corresponding measure on the other side, i.e. for transport firms.[227]

To understand the meaning of θ it is helpful to consider the scale of this parameter in terms of Euro per time saved in hours or minutes. It is straight forward that the product of θ with the time saved due to the intermediary represents the traveller's valuation of the service. This is tantamount to the willingness to pay. Looking at the scale this willingness to pay is gauged in money terms and can be compared to the price passengers have to pay to the intermediary. This price is defined to be p_p, where the index identifies the price as the one charged to passengers. Putting both willingness to pay and price together gives travellers' surplus:

$$r_p = max(\theta s - p_p, 0) \tag{6.2}$$

Where the time saved is represented by s.[228] r_p can take values in the domain $\mathbb{R}_+$. This means travellers may decide to use such an intermediation service when $\theta s \geq p_p$ and refrain from using it otherwise receiving zero surplus. In the case, where a passenger desists from the service, he will nevertheless travel, but he will

[226] Therefore, the discussion departs from an understanding that the distribution is associated to a probability.
[227] Cf. description of κ_α below.
[228] Note, passengers will only value the service of an intermediary when it reduces travel time. Therefore, $s \in \mathbb{R}_+$.

make the decision given by the information he has obtained before or by other means. Alternatively, he will fall back on traditional ticketing machines. A further possibility would be for the passenger to choose an owned car or bicycle and perform the ride by individual transport.[229]

On the other market side of the market, transport firms evaluate the benefit the intermediary offers, too. Since a platform with a payment feature provides a sales channel for transport firms, they benefit from this channel as they can monetise the presence of travellers and reduce cost of sales. The extend, to which these transport firms are able to do this, is most certainly different between these firms. Reasons are size differences with respect to transport capacity or constraints regarding (spatial) transport licences. Therefore, it makes sense to assume heterogeneity among these firms. Once again, a uniform distribution is a simplification of the true nature, but at the same time it keeps analytics less complex.

What exactly is the heterogeneous characteristic of these firms? To find a precise definition it makes sense to look at the benefits firms derive from platform usage. Taking the sales (channel) argument, firms benefit when the created profit by additional sales covers the fees to the intermediary or by offering lower average cost of sales than extant means to market their services. Thus, a simple form of transport firms' surplus functions would be: profits on platform minus fees of platform. This raises the question, how these *profits on platform* can be generalised? Assuming the indirect network effect exercised by the affiliated travellers gives the first part of these profits. Multiplying these with the expected net profits generated per traveller on the other market side results in the profits obtained on the platform. Consequently, transport firms take into account how much additional revenue is created by joining the platform. However, these firms are well aware of their own costs associated with the rides conducted by travellers. Therefore, it makes sense for them to just take the profit (generated by the physical relocation itself) as their decision variable. Thus, expenses associated with other sales channels must be

[229] The ride booked via an intermediary can also be assigned to individual transport in case of sharing services.

netted on a per customer basis, meaning cost of capital and fuel for the physical transport infrastructure are outside the scope of platform affiliation.

The parameter for this additional profit expected by transport firms is denoted by α. Similar to travellers' expected time savings (θ) α is assumed to be uniformly distributed between a lower and upper bound labeled as α_l and α_u, respectively. To account for market size of transport firms the parameter κ_α is introduced giving the mass of the distribution:

$$\alpha \sim U(\alpha_l, \alpha_u) \text{ with density } \frac{\kappa_\alpha}{\alpha_u - \alpha_l} \tag{6.3}$$

The transport firms' surplus follows then as:

$$r_t = max(\alpha D_p - p_t, 0) \tag{6.4}$$

where D_p denotes the number of travellers active on the platform and p_t denotes the prices a platform charges transport firms.

Demand of travellers results from Equation (6.2) and the consideration of who will use the intermediary. Therefore, the indifferent traveller has to be identified with respect to his or her valuation of expected time saved (θ).[230] This traveller's valuation of expected time saving is denoted by θ_{ind}. It can be found by setting $\theta s - p_p = 0$, resulting in:

$$\theta_{ind} = \frac{p_p}{s}$$

Demand follows by integrating over the uniform distribution of θ from θ_{ind} to θ_u:[231]

$$D_p(p_p, s) = \int_{\theta_{ind}}^{\theta_u} \theta \; d\theta = \frac{\kappa_\theta}{\theta_u - \theta_l} \left(\theta_u - \frac{p_p}{s}\right)$$

[230] Since the maximum condition in Equation (6.2) allows for multiple indifferent travellers, the one with the highest value of θ marks the fringe between joining the platform or refraining.

[231] Alternatively, integration from the lower bound θ_l to the indifference point θ_{ind} leads to the share of non-users. Subtracting this number from the overall size of travellers κ_θ leads to the same result.

Analogously, demand by transport firms can be derived via the indifferent transport firm for which $\alpha D_p - p_t$ holds with equality. This transport firm's additional expected profit through platform usage is defined to be α_{ind}. That gives:

$$D_t(p_t, D_p(p_p, s)) = \int_{\alpha_{ind}}^{\alpha_u} \alpha \; d\alpha = \frac{\kappa_\alpha}{\alpha_u - \alpha_l}\left(\alpha_u - \frac{p_t}{D_p(p_p, s)}\right) \tag{6.5}$$

The intermediary itself controls the three decision variables s, p_p and p_t. At the end of the day, a platform's objective function is the profit function. This function consists of three parts. Two of these are the revenue created on either market side. The third term is the cost associated with an increase in expected travel time reduction s of passengers. Without loss of generality this cost function is convex in s, meaning it increases progressively in the parameter. This is tantamount to decreasing marginal returns. To specify such a cost function a quadratic form is chosen. This suffices the requirements (convexity) while preserving a parsimonious form:[232]

$$c(s) = \eta s^2 \tag{6.6}$$

Even though having a functional form for cost associated with the expected time savings by the intermediary, requires additional justification. At a first glance these costs seem to be based on the development of a front-end interface for customers such as a mobile app. Another task of the intermediary is to coalesce all the schedules, payment interfaces and data sources of the affiliated transport firms. On top of these developments a mechanism to optimise travel time of passengers needs to be implemented. These costs can largely be considered as sunk. These developments need to be carried out only once and are irreversible. Furthermore, running costs and adjustments to the algorithm represent recurring costs. In how far these are associated with quality s, i.e. the expected time savings, remains open.

[232]This approach is common in the literature on vertical differentiation. See e.g. Woeckener (2014b).

The parameter η can consequently be seen as a cost factor for development. Taking a perennial view, the parameter can also be considered as the associated capital costs per period. Thereby, the choice of s marks a commitment by a platform and the costs are sunk.

Collecting all three terms, the profit function of an intermediary can be written as:

$$\Pi(s, p_p, p_t) = p_p D_p + p_t D_t - c(s) \tag{6.7}$$

6.1.3 Profit maximisation

To maximise the profit function the platform will proceed in two steps. The decision on the investment in the quality variable s can be interpreted as an intertemporal choice. Due to the characteristics as sunk development costs, the platform will decide on the provided level of time savings first. In the second step, the intermediary simultaneously determines prices on both market sides. However, the platform will solve this game recursively such that it maximises profits with respect to prices first receiving a reduced profit function in terms of s and the involved parameters, only. This function can then be maximised with respect to s.

The astute reader may have noticed that the profit function is not necessarily well behaved due to the network externality in the second term on the right side of Equation 6.7. Furthermore, demand may only take values between zero and the mass enveloped by the limits and densities of passengers and transport firms.

As a consequence, maximisation must consider these peculiarities. The demand restrictions can be formulated as four constraints:

$$D_p \geq 0 \tag{6.8}$$

$$D_p \leq \kappa_\theta \tag{6.9}$$

$$D_t \geq 0 \tag{6.10}$$

$$D_t \leq \kappa_\alpha \tag{6.11}$$

Stage 1: price choice

With these constraints the problem of the first stage can be formulated in Kuhn-Tucker form including five conditions:

1) Primal feasibility (a): equality constraints (Lagrange): none.

2) Primal feasibility (b): inequality constraints:

$$\begin{aligned} h_1(p_p) &= p_p - s\theta_u \leq 0 \\ h_2(p_p) &= \frac{\kappa_\theta}{\theta_u - \theta_l}(s\theta_u - p_p) - s\kappa_\theta \leq 0 \\ h_3(p_p, p_t) &= p_t - \frac{\kappa_\theta \alpha_u}{\theta_u - \theta_l}\left(\theta_u - \frac{p_p}{s}\right) \leq 0 \\ h_4(p_p, p_t) &= \frac{\kappa_\theta \alpha_l}{\theta_u - \theta_l}\left(\theta_u - \frac{p_p}{s}\right) - p_t \leq 0 \end{aligned}$$

3) Gradient:

$$\nabla \Pi(p_p^*, p_t^*) - \sum_{i=1}^{4} \mu_i \nabla h_i \overset{!}{=} 0$$

4) Dual feasibility:

$$\mu_i \geq 0$$

5) Complementary slackness:

$$\mu_i h_i \overset{!}{=} 0.$$

In condition 3) the gradient is taken with respect to prices p_p and p_t. μ_i denotes the multiplier of the inequality constraints defined in 2). These inequality constraints are a reformulation of the constraints on demand on both market sides in Equations (6.8) to (6.11). Solving the equation system of six unknowns by conditions 3) and 5) yields the results summarised in Table 6.1. Unsurprisingly, the non-negativity constraint for passengers is never binding as μ_1 is zero for all six cases. This can be explained by the profit function in Equation (6.7) and the fact that a platform requires passengers to create the network externality. Subsequently, transport firms join and use the platform. Thus, the question of the chicken & egg problem may be explicitly solved with this model as passengers are required in the first place.[233]

The six solution candidates need to be checked with regards to the five conditions of the Kuhn-Tucker formulation above. Since the solution results from conditions 3) and 5) as well as condition 1) does not contain any constraints, primal and dual feasibility have to be validated using conditions 2) and 4).

Dual feasibility

Starting with dual feasibility, solution candidates #5 and #6 can be excluded immediately as in both cases μ_3 takes on negative values contradicting the condition that $\mu_3 \geq 0$ as demanded by dual feasibility.

The cases where all transport firms join (#2 and #4) are further constrained with regards to parameter choices due to μ_4. To satisfy dual feasibility the term must be greater or equal to zero which requires that $2\alpha_l - \alpha_u$ remains non-negative. By definition $\alpha_u > \alpha_l$, leading to the condition that $\frac{\alpha_u}{\alpha_l} \leq 2$, meaning that α_l takes values that are at least half that of α_u. This restraints heterogeneity among transport firms. Going back to the discussion of vertical differentiation in Chapter 3, this result complies with the findings of Wauthy (1996). In his duopoly model, a reduced heterogeneity of this extend leads to market coverage with preemption of one firm.[234]

Furthermore, cases #3 and #4 take additional constraints to comply with $\mu_2 \geq 0$. Similarly, the conditions require that passengers are not too heterogeneous $(2\theta_l - \theta_u)$.

[233] As a consequence this frist constraint could also be dropped in the first place. However, for sake of completeness the constraint has been included. The results in Table 6.1 remain unchanged when the constraint is left aside, except that the column of μ_1 vanishes.

[234] Further note that the prices charged to transport firms p_t also comply with the result by Wauthy since for both case #2 and #4 the price p_t is the product of the transport firms lower bound α_l and the demand by passengers that represent the *quality* parameter to transport firms. Namely, these are $D_{p,\#2} = \frac{\kappa_\theta(\theta_u s + \alpha_l \kappa_\alpha)}{2s\Delta\theta}$ and $D_{p,\#4} = \kappa_\theta$. Compare these results with Wauthy (1996, p. 348).

Table 6.1: Solution candidates of constraint maximisation (stage 1) in a monopoly setting

Solution	p_p	p_t	μ_1	μ_2	μ_3	μ_4	Comment
#1	$\frac{4\theta_u s\Delta\alpha-\alpha_u^2\kappa_\alpha}{8\Delta\alpha}$	$\frac{4s\alpha_u\theta_u\kappa_\theta\Delta\alpha+\alpha_u^3\kappa_\alpha\kappa_\theta}{16s\Delta\alpha\Delta\theta}$	0	0	0	0	No binding constraints
#2	$\frac{\theta_u s-\alpha_l\kappa_\alpha}{2}$	$\alpha_l\frac{\kappa_\theta(\theta_u s+\alpha_l\kappa_\alpha)}{2s\Delta\theta}$	0	0	0	$\frac{\kappa_\alpha(2\alpha_l-\alpha_u)}{\Delta\alpha}$	All transport firms join
#3	$s\theta_l$	$\frac{\alpha_u\kappa_\theta}{2}$	0	$(2\theta_l-\theta_u)+\frac{\alpha_u^2\kappa_\alpha}{4s\Delta\alpha}$	0	0	All passengers join
#4	$s\theta_l$	$\alpha_l\kappa_\theta$	0	$(2\theta_l-\theta_u)+\frac{\alpha_l\kappa_\alpha}{s}$	0	$\frac{\kappa_\alpha(2\alpha_l-\alpha_u)}{\Delta\alpha}$	Both all passengers and transport firms join
#5	$s\theta_l$	$\alpha_u\kappa_\theta$	0	$2\theta_l-\theta_u$	$\frac{-\alpha_u\kappa_\alpha}{\Delta\alpha}$	0	All passengers join, no transport firms join
#6	$\frac{\theta_u s}{2}$	$\frac{\alpha_u\theta_u\kappa_\theta}{2\Delta\theta}$	0	0	$\frac{-\alpha_u\kappa_\alpha}{\Delta\alpha}$	0	No transport firms join

Table 6.2: Parameter restrictions due to dual feasibility requirements of stage 1 in a monopoly setting

Solution candidate	μ_2	μ_4
#1	—	—
#2	—	$2 \geq \frac{\alpha_u}{\alpha_l}$
#3	$(2\theta_l - \theta_u) + \frac{\alpha_u^2 \kappa_\alpha}{4s\Delta\alpha} \geq 0$	—
#4	$(2\theta_l - \theta_u) + \frac{\alpha_l \kappa_\alpha}{s} \geq 0$	$2 \geq \frac{\alpha_u}{\alpha_l}$

However, both restrictions are relaxed by the characteristics of the other market side and the level of quality to passengers s. Specifically, these amendments are given by $\frac{\alpha_u^2 \kappa_\alpha}{4s\Delta\alpha}$ and $\frac{\alpha_l \kappa_\alpha}{s}$. Once again, the parallels to Wauthy's preemption case are noticeable both in prices as the product of the quality parameter and the lower limit of the passengers' distribution of willingness to pay and in the parameter restriction itself. There, the first term corresponds to Wauthy's restriction that is relaxed by the described second term due to the other market side.

Alternatively, these restrictions derived from the initial constraint $h_2(p_p)$ can be reformulated in terms of s. Thus, for $\mu_2 \geq 0$ the following conditions must hold:

$$\#3: \qquad s \leq 4\Delta\alpha \frac{\alpha_u^2 \kappa_\alpha}{\theta_u - 2\theta_l}$$
$$\#4: \qquad s \leq \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$$

The analysis of dual feasibility shows that only four of the six solution candidates are valid. Table 6.2 presents the results for the four valid candidates requiring further restrictions with regards to parameters on three cases.

Primal feasibility

With numerical textbook problems primal feasibility is usually given for non-binding constraints.[235] However, due to the parameterised nature of the present problem all constraints need to be revised. Derivation of the restriction following

[235] Cf. Simon and Blume (2006, p. 428).

primal feasibility requirements are listed in Appendix D. The results are summarised in Table 6.3.

It can be seen that for the constraint on minimum transport firm participation ($h_3(p_p, p_t)$) and for case #4 no further constraints have to be imposed. Cases #1 and #3 are further restrained by constraint $h_4(p_p, p_t)$ limiting transport firm participation. These conditions are complementary to the ones obtained from dual feasibility where cases #2 and #4 required transport firms not to be too heterogeneous. The restrictions here are exactly opposite. They demand that the expected profit generated through platform participation must be at least twice the size for firms with highest platform valuation (α_u) in comparison to those with the lowest valuation (α_l).

Solution candidates #1 and #2 require further restrictions due the limitation of passengers ($h_2(p_p)$). In both cases, the quality parameter s measuring the expected time saving an intermediary provides needs to surpass a threshold. To exceed this threshold in the first place, passengers have to be rather heterogeneous. Specifically, the following relationship has to hold: $\theta_u - 2\theta_l > 0$.

For case #1, an increased heterogeneity among both market sides shifts this threshold to the left. This makes sense as passengers are less likely to all join the service due to differences in willingness to pay. At the same time, more heterogeneous transport firms increase prices p_p for passengers also making it less likely that passengers join in their entirety.[236] The number of transport firms κ_α and the highest valuation of passengers by transport firms have a reverse effect. Both considerations rely on the number of transport firms about to join a platform and the revenue it can extract from this market side.

When all transport firms join in the first place (case #2), the effect of transport firms' heterogeneity is obviously no longer relevant, but only market size κ_α and the firm struggling most to monetise the passenger demand on the platform (denoted by α_l) determine the *discount* passengers receive making it more likely for them to all use the intermediaries services. Thus, the threshold is shifted to the right when these parameters take higher values.

[236] See price function p_p for case #1 in Table 6.1.

Table 6.3: Parameter restrictions due to primal feasibility requirements of stage 1 in a monopoly setting

Solution candidate	$h_2(p_p)$	$h_3(p_p, p_t)$	$h_4(p_p, p_t)$
#1	$s \geq \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)}$	—	$2 \leq \frac{\alpha_u}{\alpha_l}$
#2	$s \geq \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$	—	—
#3	—	—	$2 \leq \frac{\alpha_u}{\alpha_l}$
#4	—	—	—

To conclude this first stage on price competition, the reduced profit functions are derived together with a summary of the relevant constraints. These functions result by substituting prices p_p and p_t from Table 6.3 in the general profit function, given in Equation (6.7). This yields:

$$\begin{aligned}\Pi_{\#1}(s) &= \frac{\kappa_\theta}{s\Delta\theta}\frac{(4s\Delta\alpha\theta_u)^2 - (\alpha_u^2\kappa_\alpha)^2}{(8\Delta\alpha)^2} + \frac{\kappa_\theta}{s\Delta\theta}\frac{\alpha_u^2\kappa_\alpha(4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha)}{32(\Delta\alpha)^2} - c(s) \\ &= \frac{\kappa_\theta}{s\Delta\theta}\left(\frac{4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha}{8\Delta\alpha}\right)^2 - c(s) \end{aligned} \tag{6.12}$$

$$\begin{aligned}\Pi_{\#2}(s) &= \frac{\kappa_\theta}{s\Delta\theta}\frac{(s\theta_u)^2 - (\alpha_l\kappa_\alpha)^2}{4} + \frac{\kappa_\theta}{s\Delta\theta}\frac{\alpha_l\kappa_\alpha(s\theta_u + \alpha_l\kappa_\alpha)}{2} - c(s) \\ &= \frac{\kappa_\theta}{s\Delta\theta}\left(\frac{s\theta_u + \alpha_l\kappa_\alpha}{2}\right)^2 - c(s) \end{aligned} \tag{6.13}$$

$$\Pi_{\#3}(s) = s\theta_l\kappa_\theta + \frac{\alpha_u^2\kappa_\alpha\kappa_\theta}{4\Delta\alpha} - c(s) \tag{6.14}$$

$$\Pi_{\#4}(s) = s\theta_l\kappa_\theta + \alpha_l\kappa_\alpha\kappa_\theta - c(s) \tag{6.15}$$

The first lines of Equations (6.12) and (6.13) give the separated revenues generated on either market side. Namely, revenue with passengers is the first term and with transport service providers the second.

Equations (6.12) and (6.13) are clearly more complex than the latter two reduced profit functions in (6.14) and (6.15). That is due to fewer restrictions in (6.14) and (6.15). As a consequence, these functions keep the quality variable s in the revenue parts as a linear dependence and to the power of minus one. The negative power is maintained due to the occurrence in the fraction of transport firm's surplus function r_t in Equation (6.4) and the corresponding demand function D_t in Equation (6.5).

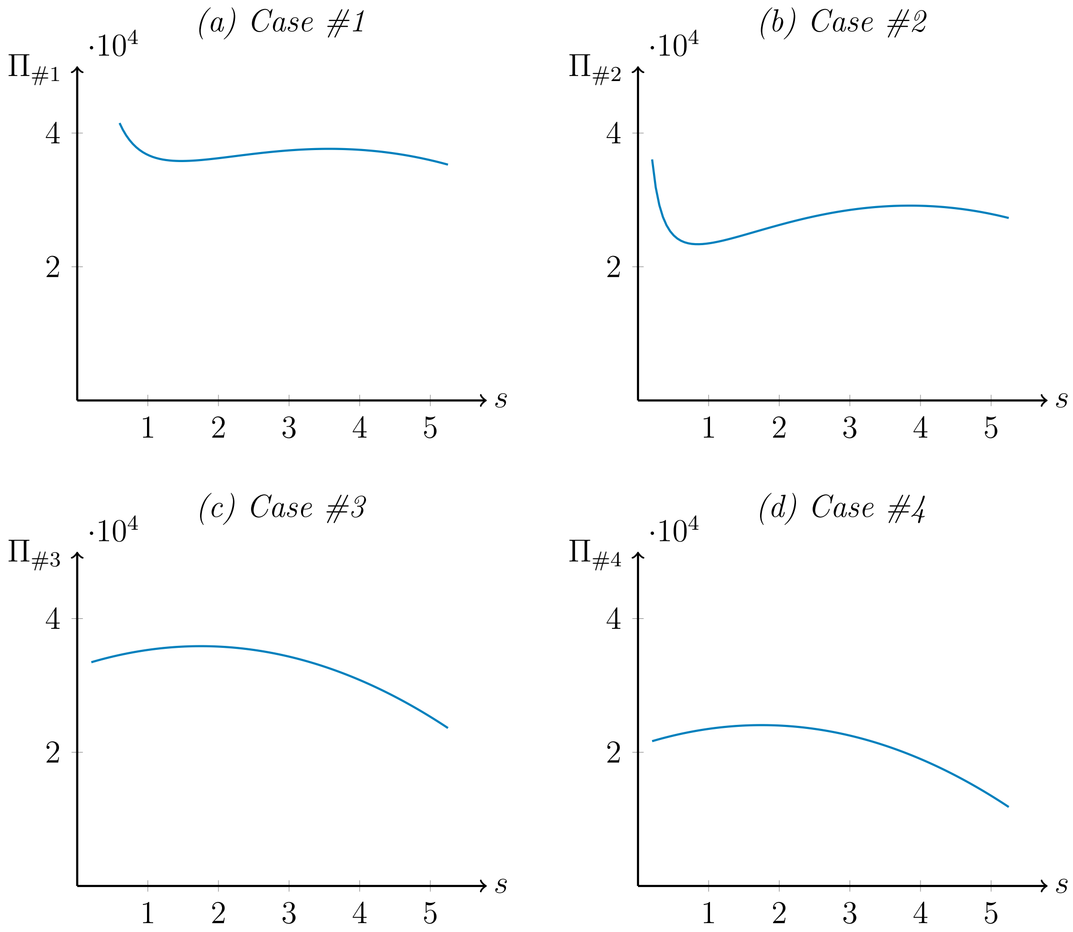


Figure 6.1: Profit functions for a monopoly platform

Parameters are only constrained to μ_4. I.e. for all cases $\alpha_l = 0.1$, $\theta_l = 0.5$, $\theta_u = 4$, $\kappa_\alpha = 30$, $\kappa_\theta = 7,000$ and $\eta = 1000$ are applied. For cases #1 and #3 $\alpha_u = 0.5$ while for cases #2 and #4 $\alpha_u = 0.15$ to insure $\frac{\alpha_u}{\alpha_l} \leq 2$.

As Figures 6.1 (a) and (b) illustrate, this negative power may lead to non-concave profit functions.

In the more restrained cases in Equations (6.14) and (6.15)i where all passengers join, the simplification of passengers' demand $D_p = \kappa_\theta$ leads to reduced revenue functions that are linear in s. This follows immediately, as the parameter requirements for exogenous passenger demand make sure that all passengers join. Consequently, Figures 6.1 (c) and (d) show these reduced profit functions as concave functions where solely quadratic costs determine the course of the functions.

In the next step these reduced profit functions in Equations (6.12) to (6.15) are maximised with regards to the expected time savings a platform generates, i.e. s. Thereby, the non-concavities and parameter restrictions identified above are both taken into account.

Stage 2: quality choice

Ultimately, an intermediary has to decide what quality it offers to the market side directly valuing the service the intermediary offers. For transport intermediation, this question can be posed as how much will a platform invest to achieve a level s of expected time savings for passengers. As in the previous section established, four cases remain. These cases will be assessed in pairs as the structure of case #1 and #2 are roughly similar and the two remaining cases #3 and #4 feature a similar structure.

In the case where none of the four initial constraints is binding, the reduced profit function in Equation (6.12) contains the variable s in both quadratic or linear form and as an inverse due to the demand interdependence between transport firms and passengers. Depending on parameter choice, this profit function has, generally, up to two local maxima and one minimum. The domain has been defined to take only positive values ($s \geq 0$), thus, one of these local maxima drops out.

Looking into the maximisation as a whole, the restrictions due to the first stage that include the quality variable s need to be accounted for. Consequently, optimising profits has again to be done using a Kuhn-Tucker approach. For case #1, only the constraint $s \geq \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)}$, due to primal feasibility in the first stage, depends on the value of s. Therefore, the Kuhn-Tucker problem can be posed as:

1) Primal feasibility (a): equality constraints (Lagrange): none.

2) Primal feasibility (b): inequality constraints:

$$h_1(s) = \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)} - s \leq 0 \tag{6.16}$$

3) Gradient:

$$\frac{\partial \Pi_{\#1}(s)}{\partial s} - \mu_1 \frac{\partial h_1}{\partial s} \stackrel{!}{=} 0$$

4) Dual feasibility:

$$\mu_1 \geq 0$$

5) Complementary slackness:

$$\mu_1 h_1 \stackrel{!}{=} 0.$$

Solving the system of the gradient and complementary slackness results in four solutions. The number of solutions is higher than the number of equations, as the gradient of the profit function in Equation (6.12) contains s to the third power.

Of the solutions, there are three for the unconstrained problem and one, where the inequality constraint is binding. The binding solution corresponds to the restriction from above with equality:

$$s^*_{\#1,binding} = \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)}$$

The remaining solutions follow from the First Order Condition (FOC) of the profit function. This condition is explicitly given by:

$$\frac{\partial \Pi_{\#1}(s)}{\partial s} = \frac{\Delta\alpha\theta_u(4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha)\kappa_\theta}{8s(\Delta\alpha)^2\Delta\theta} - \frac{(4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha)^2\kappa_\theta}{64s^2(\Delta\alpha)^2\Delta\theta} - 2\eta s \stackrel{!}{=} 0 \quad (6.17)$$

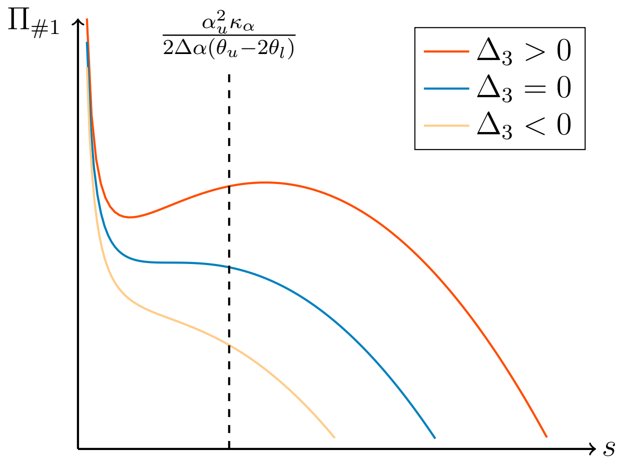


Figure 6.2: Behaviour of the reduced monopoly profit function for the case when no demand constraints are binding

After multiplying this equation by s^2, it is straightforward to see that it is cubic. For solutions of cubic equations, there may occur three cases depending on the discriminant of the cubic. For

$\Delta_3 > 0$	the equation has three distinct real roots,
$\Delta_3 = 0$	the equation has at least a repeated root and all roots are real,
$\Delta_3 < 0$	the equation has a real root and two complex conjugate roots.

Δ_3 denotes the discriminant of the cubic equation. To illustrate these configurations Figure 6.2 shows these cases for a positive domain along the reduced profit function in Equation (6.12).[237] The red line denotes the case where $\Delta_3 > 0$. Here, a local minimum and maximum can be identified. These points refer to the roots of the FOC in Equation (6.17). In blue, the case where $\Delta_3 = 0$ is drawn. Here, the two roots from the red line have converged and mark a saddle point. As soon as the Δ_3 becomes less than zero, the function has no positive real root. This case is shown in yellow below the two other curves.[238]

[237] Thus, the existing negative real root is not shown Figure 6.2, as the present problem is posed for $s \in \mathbb{R}_+$, only.

[238] Appendix E elaborates on the derivation of these roots.

So far, the graph suggests that a platform lacks an incentive to invest in s at all, since profits are asymptotically increasing as s approaches zero. However, the constraint in the Kuhn-Tucker problem $s \geq \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)}$ ensures that only points to the right of a local minimum are feasible (in case of $\Delta_3 > 0$).[239] In sequence, only a positive discriminant may lead to an interior solution.[240] Otherwise, the platform will choose s as low as possible, driving it to the bounded solution where, ultimately, the passenger market is just-covered.

It remains to specify the discriminant of the converted FOC in Equation (6.17). Standard techniques lead to the following expression:[241]

$$\Delta_3 = \frac{\alpha_u^4 \kappa_\theta^2 \kappa_\alpha^2 \big((\theta_u^3 \Delta\alpha\kappa_\theta)^2 - 27(\alpha_u^2 \Delta\theta\kappa_\alpha\eta)^2 \big)}{1024(\Delta\alpha\Delta\theta)^4} \tag{6.18}$$

As all parameters are positive by definition, Equation (6.18) is positive as long as the large parentheses encircle a positive difference. The condition to be met is:

$$\frac{\frac{\kappa_\theta}{\Delta\theta}}{\frac{\kappa_\alpha}{\Delta\alpha}} \frac{\theta_u^3}{\alpha_u^2 \eta} > \sqrt{27} \tag{6.19}$$

This condition shows that the characteristics of the distributions (of passengers and transport firms) are inversely related. While a larger market size of passengers (denoted by κ_θ) increases the term on the left side of the condition and, thus, increases the likelihood of an interior solution, the size of transport firms (κ_α) has an effect in the opposite direction. With regard to heterogeneity among both parties, more diverse passengers (greater value of $\Delta\theta$) decrease the size of the left term in (6.19) while the difference of transport firms to monetise passengers affiliated to the intermediary ($\Delta\alpha$) enters the condition in the enumerator. Therefore, a greater

239 The location of this threshold is never to the left of a possible local minimum. This can most easily be shown, by comparison of the converged local extrema in case of $\Delta_3 = 0$ with the constraint. Alternatively, the same result can be shown numerically by comparing the value where this restriction holds with the exact solution of a local minimum described in Appendix E, namely s_3^{trig}.

240 Similarly to the position of the local minimum, the maximum's s-value given a positive discriminant can be computed numerically using s_1^{trig} defined in Appendix E. If this value is greater than the threshold, an interior local maximum exists.

241 Note that both $\Delta\alpha$ and $\Delta\theta$ relate to the characteristics of the distribution in terms of the difference between the distributions' limits. They are not to be mixed up with discriminates.

difference among transport firms can lead to an interior maximum. Stated differently, the densities on both market sides have an inverse effect on the discriminant. The density of passengers increases the discriminant while transport firms' density leads to lower values.[242]

The upper limits of the distributions, i.e. the passengers with the highest willingness to pay and the transport firms that can extract most revenue from passengers using the platform, enter the condition outside the heterogeneity variables $\Delta\alpha$ and $\Delta\theta$, too. As with the distributions, the upper limit of passengers θ_u has a positive effect on the fraction in (6.19) while transport firms' limit α_u decreases the fraction as it takes greater values. In addition, these two parameters enter the condition to the power of three and two for passengers and transport firms, respectively. Consequently, these values have ambiguous effects as they enter the condition in both the enumerator and denominator. However, the power terms dominate the heterogeneity effects.

It is straight forward that greater costs resulting from higher η shift the profit functions down. In consequence, a local maximum may cease to exits. In condition (6.19) the η in the denominator takes account for this effect.

For case #2, where all transport firms join, the reduced profit function (Equation (6.13)) has a similar structure due to the effect of passengers' demand characteristics. Once again, the problem of the intermediary can be formulated as a Kuhn-Tucker problem. The parameter restriction $h_2(p_p)$ in the first stage needs to be considered. Therefore, a new inequality constraint is set up:

$$h_1(s) = \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l} - s \leq 0 \tag{6.20}$$

The gradient of the profit function $\Pi_{\#2}(s)$ and the constraint (6.20) together with the corresponding complementary slackness condition gives a system of equations

[242] For uniform distributions the density is given by the fraction of mass and the difference in the distribution's limits. In case of passengers, this is $\frac{\kappa_\theta}{\Delta\theta}$.

with four solutions for s. Similarly to the approach above, the straight forward solution is the one where $h_1(s)$ is binding:

$$s^*_{\#2,binding} = \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$$

The shape of the profit function is, as Figure 6.2 graph (b) illustrates, alike to the one of the unconstrained problem in case #1. Thus, it can be expected that the remaining solutions are in analogy to the non-binding solutions in case #1. For the analysis of the unconstrained solution, it remains to use the FOC of $\Pi_{\#2}(s)$:

$$\frac{\partial \Pi_{\#2}(s)}{\partial s} = \frac{\theta_u(s\theta_u + \alpha_l\kappa_\alpha)\kappa_\theta}{2s\Delta\theta} - \frac{(s\theta_u + \alpha_l\kappa_\alpha)^2\kappa_\theta}{4s^2\Delta\theta} - 2s\eta \stackrel{!}{=} 0 \tag{6.21}$$

As with case #1, multiplying this equation by s^2 leads to a cubic with three roots.[243] The discriminant to Equation (6.21) can be written as:

$$\Delta_3 = \frac{\alpha_l^2\kappa_\alpha^2\kappa_\theta^2\big(\theta_u^6\kappa_\theta^2 - 432\alpha_l^2\eta^2(\Delta\theta)^2\kappa_\alpha^2\big)}{64(\Delta\theta)^4} \tag{6.22}$$

Equation (6.21) will have three real roots when the discriminant in (6.22) is greater than zero. This is satisfied given:

$$\frac{\theta_u^6\kappa_\theta^2}{\alpha_l^2(\Delta\theta)^2\kappa_\alpha^2\eta^2} > 432 \tag{6.23}$$

Note that α_l cannot take too small values for case #2 as the criterion derived from dual feasibility above $\frac{\alpha_u}{\alpha_l} \leq 2$ must be satisfied. Therefore, the denominator in (6.23) is strictly positive.

Together with the restriction that some passengers refrain from joining the platform, namely $s \geq \frac{\alpha_l\kappa_\alpha}{\theta_u - 2\theta_l}$ due to primal feasibility, the intermediary may have ample motivation to increase the service quality for passengers to a certain extend. As with the first case, it can happen that this condition on s lies to the right of the local maximum. In that case the platform will tend to a lower value in s and, thus, approaches the case of market coverage for passengers.

[243] Cf. Appendix E.

In the same spirit, a negative discriminant, tantamount to only one (negative) real root in the FOC in (6.21), leads the monopolist to decrease s and, thus, to a situation where all passengers join.

When all passengers use the platform's service and some transport firms stay away from the intermediary (case #3) the reduced profit function contains only a linear revenue term (in s) and the quadratic cost function. The FOC is given by:

$$\frac{\partial \Pi_{\#3}(s)}{\partial s} = \theta_l \kappa_\theta - 2s\eta \overset{!}{=} 0 \tag{6.24}$$

Consequently, the optimal quality choice is:

$$s^*_{\#3} = \frac{\theta_l \kappa_\theta}{2\eta} \tag{6.25}$$

In the remaining fourth case revenue is linear, too. Thus, taking the partial derivative with respect to s yields the same FOC as in (6.24):

$$\frac{\partial \Pi_{\#4}(s)}{\partial s} = \theta_l \kappa_\theta - 2s\eta \overset{!}{=} 0$$

And the platform will choose $s^*_{\#3} = s^*_{\#4}$.

6.1.4 Summary of the monopoly case

To conclude the discussion of a monopoly platform and its decisions to set prices and to determine its service level to passengers, the four cases and their parameter restrictions are synthesised.

There are four possible demand configurations that may appear to a monopolist. These include the combinations where passengers and transport firms either join partly or in their entirety. The discussion above showed that for the transport firm side the rules of one-sided vertical differentiation apply. Thus, this group will partly join the platform as long as it exhibits enough heterogeneity, i.e. $\frac{\alpha_u}{\alpha_l} \geq 2$. Otherwise, $2 \geq \frac{\alpha_u}{\alpha_l} > 1$ holds, meaning all transport firms join the platform.

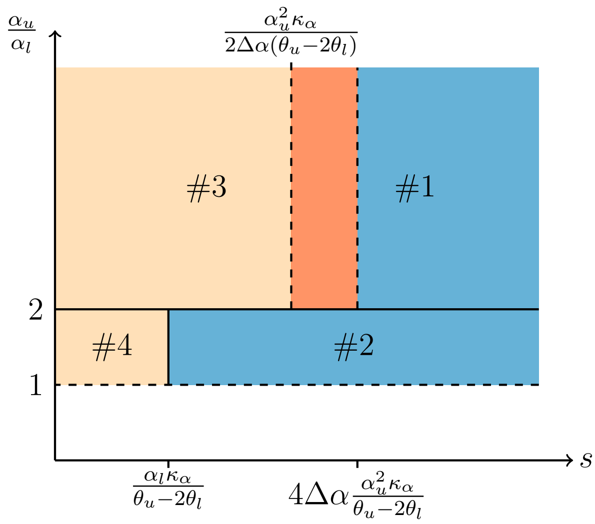


Figure 6.3: Segmentation of the parameter space for monopoly platforms

The light areas mark the parameter space where all passengers are affiliated to the platform and where the reduced profit functions are strictly concave. In blue, passenger demand is unconstrained and the reduced profit functions may not be well-behaved. The red area marks the intersection where the restrictions due to μ_2 overlap.

In Figure 6.3 transport firms heterogeneity is measured on the ordinate. At $\frac{\alpha_u}{\alpha_l} = 2$ a line marks the threshold between the configurations where all firms join (bottom) and where only a subset of transport firms will use the platform (top). For travellers on the other market side not only the distribution parameters towards their valuation of the expected time saved by the platform determines market coverage. The Lagrange multipliers μ_2 (for cases #3 and #4) and the primal feasibility condition on market coverage contain the quality variable making it a further determinant for the market configuration. Only given market coverage among transport firms, a clear cut threshold exits between cases #2 and #4. While in the remaining cases (where $\frac{\alpha_u}{\alpha_l} \geq 2$) the parameter constraints are overlapping. In Figure 6.3 this is shown by the red area.

To analyse the choice of s the profits of cases #1 and #3 and the profits of the cases where all transport firms are affiliated to the intermediary, namely, cases #2 and #4 need to be compared pairwise. Starting with the uncovered transport firms' market, profits in case #1 are always greater than in case #3 (for the same parameters and the same choice of variable s in the permissible area). This can easily be shown by subtracting Equation (6.14) from (6.12) which is greater than zero.

Once an intermediary considers different levels of s, the picture is no longer clear cut. The reason lies in the shape of the profit function in case #1. As it was shown above, an intermediary will reduce its quality to the minimum value given the discriminant in Equation (6.18) takes negative values. Together with the case where the discriminant is positive, but market coverage is sustained, i.e. where the local maximum of $\Pi_{\#1}$ lies to the left of the threshold set by μ_2, the platform chooses a level of quality that maximises $\Pi_{\#3}$. This unambiguously leads to a lower value of s. It remains to compare profits attained at the lowest valid point for case #1 i.e. $s = \frac{\alpha_u^2 \kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)}$ with maximum profit attained in case #3 at $s^*_{\#3} = \frac{\theta_l \kappa_\theta}{2\eta}$ (cf. Equation (6.25)). Substituting these values in the corresponding profit functions in Equations (6.12) and (6.14) and taking the difference yields that profits are higher for the lower quality level in case #3.

For a covered transport firms' market, the shape of the profit function in case #2 determines similarly whether this case is an option or not. In case the discriminant in Equation (6.22) is less than zero $\Pi_{\#2}$ is decreasing in s leading the intermediary to reduce quality as low as possible and ultimately to case #4. The transition between the two cases is smooth in the sense that the profit functions take the same values at the boundary. This means, the combined profit function is continuous. Once the discriminant is positive, three cases can occur:

1. There exits an interior local maximum at $s^*_{\#2} > \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$ where $\Pi_{\#2}(s^*_{\#2}) > \Pi_{\#4}(s^*_{\#4})$. Therefore, the platform chooses to invest to achieve quality level $s^*_{\#2}$.

2. There exits an interior local maximum at $s^*_{\#2} > \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$ where $\Pi_{\#2}(s^*_{\#2}) < \Pi_{\#4}(s^*_{\#4})$. Thus, the platform chooses the maximum of $\Pi_{\#4}$.

3. $\frac{\partial \Pi_{\#2}}{\partial s} < 0$ for $s \geq \frac{\alpha_l \kappa_\alpha}{\theta_u - 2\theta_l}$, thus, the maximum of $\Pi_{\#4}$ is attained.

This summary concludes the analysis of a monopoly intermediary. It was shown that the game on transport sides market has similarities to the general vertical differentiation model by Wauthy (1996) while the interdependence passengers exercise on transport firms lead to new results. To investigate the cases beyond preemption in further detail, competition is introduced in the following section.

6.2 Duopoly transport platform

In the same manner as in the previous section, the analysis of a duopoly market will be conducted. This scenario is required as in some cities there are at least two transport intermediaries and the question arises how platforms position themselves when there is competition.

6.2.1 Assumptions

With this setting, the model takes the thoughts of Wauthy (1996) back up and combines them with the approach by Roger (2017). In contrast to the preceding section surplus functions in Equations (6.2) and (6.4) are now indexed by the corresponding platform $i \in 1, 2$:

$$r_{p,i} = max(\theta s_i - p_{p,i}, 0)$$
$$r_{t,i} = max(\alpha D_{p,i} - p_{t,i}, 0)$$

Similarly, the quality measures (s_i and the positive network externality $D_{p,i}$) and prices are defined by each platform. Therefore, they contain an index i as well. Without loss of generality the two duopolists are distinguished by assuming that platform two offers a greater expected gross travel time reduction than the first platform i.e. $s_1 < s_2$.[244] As before, the platforms need to invest to achieve their

[244]That means platform 2 is the quality leader while platform 1 offers the low quality service.

Table 6.4: Passenger demand in a vertically differentiated duopoly

	$D_{p,1}$	$D_{p,2}$	$D_{p,1} + D_{p,2}$
Preempted market	0	κ_θ	κ_θ
Covered market	$\frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \theta_l\right)$	$\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)$	κ_θ
Uncovered market	$\frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \frac{p_{p,1}}{s_1}\right)$	$\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)$	$\leq \kappa_\theta$

Table 6.5: Transport firm demand in a vertically differentiated duopoly

	$D_{t,1}$	$D_{t,2}$	$D_{t,1} + D_{t,2}$
Preempted market	0	κ_α	κ_α
Covered market	$\frac{\kappa_\alpha}{\Delta\alpha}\left(\frac{p_{t,2}-p_{t,1}}{D_{p,2}-D_{p,1}} - \alpha_l\right)$	$\frac{\kappa_\alpha}{\Delta\alpha}\left(\alpha_u - \frac{p_{t,2}-p_{t,1}}{D_{p,2}-D_{p,1}}\right)$	κ_α
Uncovered market	$\frac{\kappa_\alpha}{\Delta\alpha}\left(\frac{p_{t,2}-p_{t,1}}{D_{p,2}-D_{p,1}} - \frac{p_{t,1}}{D_{p,1}}\right)$	$\frac{\kappa_\alpha}{\Delta\alpha}\left(\alpha_u - \frac{p_{t,2}-p_{t,1}}{D_{p,2}-D_{p,1}}\right)$	$\leq \kappa_\alpha$

level of s_i. The cost structure for both firms follows the same function as in the monopoly case described by Equation (6.6):

$$c_i(s_i) = \eta s_i^2 \tag{6.26}$$

To keep matters comparable, the parameter η is the same for both intermediaries. This makes sense as costs and wages for (software) developers are determined by market prices and are consequently outside of firms' influence.

The market shares follow from the rationale that has been described in Chapter 4.2. Similar to Table 4.1, there result three possible market configurations for either market side. These configurations are shown in Tables 6.4 and 6.5.

The profit functions of the duopolist can then be stated as:

$$\Pi_i(s_1, s_2, p_{p,1}, p_{p,2}, p_{t,1}, p_{t,2}) = p_{p,i}D_{p,i} + p_{t,i}D_{t,i} - c_i \tag{6.27}$$

6.2.2 Maximising duopolist's profits

Setting up a Kuhn-Tucker problem, as it has been done in the monopoly case, is the first task to tackle profit maximisation at this point. However, the gradient of the Lagrange function yields highly non-linear results with regards to prices $p_{p,1}$ and $p_{p,2}$. As a consequence, there does not exist a manageable and intuitive solution to the problem. To cope with this issue, the intuition of platforms behaviour on either side is analysed.

In Equation (6.27), prices on travellers' market side only appear in the second term of the duopolists' profit function. Thus, from travellers' point of view the decision conforms to standard vertical differentiation as introduced above.[245] Maximising this part of revenue subject to restrictions on travellers' demand yields optimal prices on this market side.

It can easily be shown using the demands in Tables 6.4 and 6.5 that the demands of the high quality platform are always greater than those of its low quality competitor. Therefore, mixed quality leadership on either market can be ruled out. This implies that the quality leader in the passenger market is at the same time the quality leader in the transport market and vice versa for the low quality firm.

The Kuhn-Tucker formulation to find the optimal prices charged to transport firms are as follow and include the inequality constraints due to demand restrictions on transport side given an uncovered market as described in Table 6.5. Namely, the sum of the demands need to be within the interval $[0, \kappa_\alpha]$ and $D_{t,i} \geq 0$ with $i \in \{1, 2\}$.

1. Primal feasibility (a): equality constraints (Lagrange): none.

2. Primal feasibility (b): inequality constraints:

$$\begin{aligned} h_1 &= p_{t,1}D_{p,2} - p_{t,2}D_{p,1} \leq 0 \\ h_2 &= p_{t,2} - p_{t,1} - \alpha_u(D_{p,2} - D_{p,1}) \leq 0 \\ h_3 &= \alpha_l D_{p,1} - p_{t,1} \leq 0 \end{aligned}$$

3. Gradient:

$$\nabla\Pi_i(p_{t,1}, p_{t,2}) - \sum_{j=1}^{3} \mu_j \nabla h_j \overset{!}{=} 0$$

[245] Cf. Chapter 4.2.

4. Dual feasibility:

$$\mu_j \geq 0$$

5. Complementary slackness:

$$\mu_j h_j \stackrel{!}{=} 0.$$

Where h_1 and h_2 require $D_{t,1}$ and $D_{t,2}$ to be greater or equal to zero. h_3 limits total demand to the market size κ_α.[246] The gradient and complementary slackness conditions yield five solutions listed in Table 6.6. Among these solutions, the first two are well known from the analyses in Chapter 4.2. They correspond Wauthy's prices for an uncovered and a just-covered market.

To validate all solutions the arguments of dual and primal feasibility need to be checked. It follows that the Lagrange multipliers μ_j need to be either zero or greater than zero. Furthermore, the constraints h_j evaluated at the prices of the corresponding solutions must be satisfied.

After some reformulations, the Lagrange multipliers yield the conditions listed in Table 6.7. From this list solutions #4 to #6 can be dropped without further analysis as the negative signs in Table 6.6 disqualify them as valid solutions.

For case #3, the dual feasibility criterion is not obvious. But rephrasing μ_2 to $\alpha_u(D_{p,1} - D_{p,2}) - D_{p,1}\alpha_l$ and given the definition that $D_{p,2} > D_{p,1}$ makes the left term inevitably negative. Thereby, μ_2 will be less than zero. Consequently, this solution candidate has to be discarded, too.[247]

The dual feasibility requirements for case #2 state that the fraction of highest and lowest valuation among transport firms may not exceed $\frac{4D_{p,2}-D_{p,s}}{D_{p,2}-D_{p,1}}$. As this case is known from the one-sided analysis, it is of no surprise that this condition resembles the upper bound of the just-covered market in Table 4.2. And indeed

[246] Note, κ_α drops out in h_3 when simplifying the demand condition.

[247] Note that for μ_3 to be positive, the following condition has to be true: $\frac{\alpha_u}{\alpha_l} \geq \frac{2D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}$ which would be perfectly valid result. However, neither of the Lagrange multipliers must be negative. Thus, the mere negativity of μ_2 leads to a rejection of this solution.

Table 6.6: Solution candidates of constraint maximisation (stage 1) for transport prices in a duopoly setting

Solution	$p_{t,1}$	$p_{t,2}$	μ_1	μ_2	μ_3	Comment
#1	$\frac{D_{p,1}\alpha_u(D_{p,2}-D_{p,1})}{4D_{p,2}-D_{p,1}}$	$\frac{2D_{p,2}\alpha_u(D_{p,2}-D_{p,1})}{4D_{p,2}-D_{p,1}}$	0	0	0	Unconstrained
#2	$D_{p,1}\alpha_l$	$\frac{\alpha_u(D_{p,2}-D_{p,1})+\alpha_l D_{p,1}}{2}$	0	0	$\frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,1}\Delta\alpha-D_{p,2}(\alpha_u-4\alpha_l)}{2(D_{p,2}-D_{p,1})}$	Just covered transport market
#3	$D_{p,1}\alpha_l$	$D_{p,2}\alpha_u - D_{p,1}\Delta\alpha$	0	$\frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,1}\Delta\alpha-D_{p,2}\alpha_u}{D_{p,2}-D_{p,1}}$	$\frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,1}\Delta\alpha-D_{p,2}(\alpha_u-2\alpha_l)}{D_{p,2}-D_{p,1}}$	All transport firms join low passenger demand platform
#4	$\frac{D_{p,1}\alpha_u(D_{p,2}-D_{p,s})}{2D_{p,2}-D_{p,1}}$	$\frac{2D_{p,2}\alpha_u(D_{p,2}-D_{p,1})}{2D_{p,2}-D_{p,1}}$	0	$-\frac{\kappa_\alpha}{\Delta\alpha}\frac{2D_{p,2}\alpha_u}{2D_{p,2}-D_{p,1}}$	0	Transport firms join only low passenger demand platform (no preemption)
#5	$\frac{D_{p,1}\alpha_u(D_{p,2}-D_{p,1})}{2D_{p,2}-D_{p,1}}$	$\frac{2D_{p,2}\alpha_u(D_{p,2}-D_{p,1})}{2D_{p,2}-D_{p,1}}$	$-\frac{\kappa_\alpha}{\Delta\alpha}\frac{\alpha_u}{2D_{p,2}-D_{p,1}}$	0	0	Transport firms join only high passenger demand platform (no preemption)
#6	$D_{p,1}\alpha_u$	$D_{p,2}\alpha_u$	$-\frac{\kappa_\alpha}{\Delta\alpha}\frac{\alpha_u}{D_{p,2}-D_{p,1}}$	$-\frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,2}\alpha_u}{D_{p,2}-D_{p,1}}$	0	Transport firms are absent

Table 6.7: Parameter restrictions due to dual feasibility requirements on transport side in a duopoly setting

Solution	μ_1	μ_2	μ_3
#1	—	—	—
#2	—	—	$\frac{4D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}} \leq \frac{\alpha_u}{\alpha_l}$
#3	—	$\alpha_u(D_{p,1}-D_{p,2}) \geq D_{p,1}\alpha_l$	$\frac{\alpha_u}{\alpha_l} \geq \frac{2D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}$

Table 6.8: Parameter restrictions due to primal feasibility requirements on transport side in a duopoly setting

	h_1	h_2	h_3
#1	$-D_{p,2}D_{p,1}\alpha_u(D_{p,2}-D_{p,1}) \leq 0$	$\frac{2D_{p,2}-D_{p,1}}{4D_{p,2}-D_{p,1}} \leq 1$	$\frac{4D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}} \leq \frac{\alpha_u}{\alpha_l}$
#2	$\frac{2D_{p,2}-D_{p,1}}{D_{p,1}-D_{p,2}} \leq \frac{\alpha_u}{\alpha_l}$	$-(D_{p,2}-D_{p,1})\alpha_u - D_{p,1}\alpha_l \leq 0$	—

μ_3 just states that the market is covered. For case #1 neither of the constraints is binding. Thus, this case represents a market where both competitors cater to transport firms and some of these refrain from platform participation.

The two remaining solutions satisfy primal feasibility given the restrictions in Table 6.8. Once again, these restrictions are known from the one-sided analysis. That is the case, where some transport firms refrain to affiliate with the platform (#1). It requires transport firms' valuation of the network externality to be highly heterogeneous. For this uncovered transport market configuration, the fraction of α_u to α_l needs to exceed the threshold set by $\frac{4D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}$ following from h_3.[248]

Similarly, for the just-covered market the primal feasibility condition h_1 yields the lower bound of this market configuration analogously to the bound in the one-sided case as $\frac{2D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}} \leq \frac{\alpha_u}{\alpha_l}$.[249]

[248] h_1 and h_2 are satisfied without further parameter constraints.

[249] Cf. Table 4.2 and note that condition h_2 is met irrespective of further parameter restrictions.

Table 6.9: Boundaries of market configurations for transport firms

	Preempted Market	Covered Market	Just-Covered Market	Uncovered Market
$\frac{\alpha_u}{\alpha_l}$	$(1, 2]$	$\left(2, \frac{2D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}\right)$	$\left[\frac{2D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}, \frac{4D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}\right]$	$\left(\frac{4D_{p,2}-D_{p,1}}{D_{p,2}-D_{p,1}}, \infty\right)$

Conducting the same analysis within an ex-ante covered market[250] yields a third solution. Similarly to the prices in Equations (4.2) and (4.3) transport side prices are given by:

$$
\begin{aligned}
p_{t,1} &= \frac{\alpha_u - 2\alpha_l}{3}(D_{p,2} - D_{p,1}) \\
p_{t,2} &= \frac{2\alpha_u - \alpha_l}{3}(D_{p,2} - D_{p,1})
\end{aligned}
$$

As before, the three cases are limited according to the parameter spaces listed in Table 6.9.

With the prices in terms of passenger demand, the transport demands can restated in terms of passenger demand. For the three cases this gives:[251]

$$
D_{t,1}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,2}\alpha_u}{4D_{p,2} - D_{p,1}} \tag{6.28}
$$

$$
D_{t,2}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{2D_{p,2}\alpha_u}{4D_{p,2} - D_{p,1}} \tag{6.29}
$$

$$
D_{t,1}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{1}{2}\frac{D_{p,2}(\alpha_u - 2\alpha_l) - D_{p,1}(\alpha_u - \alpha_l)}{D_{p,2} - D_{p,1}} \tag{6.30}
$$

$$
D_{t,2}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{1}{2}\frac{D_{p,2}\alpha_u - D_{p,1}(\alpha_u - \alpha_l)}{D_{p,2} - D_{p,1}} \tag{6.31}
$$

$$
D_{t,1}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\alpha_u - 2\alpha_l}{3} \tag{6.32}
$$

$$
D_{t,2}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{2\alpha_u - \alpha_l}{3} \tag{6.33}
$$

[250] Cf. Table 6.5.

[251] It can be shown that $D_{t,1}^{JCM} + D_{t,2}^{JCM} = D_{t,1}^{CM} + D_{t,2}^{CM} = \kappa_\alpha$ meaning that the transport market is covered as it is stipulated. The sum of $D_{t,1}^{UM}$ and $D_{t,2}^{UM}$ is less than κ_α as long the fraction $\frac{\alpha_u}{\alpha_l}$ exceeds the limit defined in Table 6.9. This tantamount to requiring enough heterogeneity among transport firms' valuation on the network externality exercised by passengers.

The revenues obtained by transport firms can then be restated by taking the product of Equations (6.28) – (6.33) with the respective prices in Table 6.6:

$$r_{t,1}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,1}D_{p,2}\alpha_u^2}{(4D_{p,2}-D_{p,1})^2}(D_{p,2}-D_{p,1}) \tag{6.34}$$

$$r_{t,2}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\left(\frac{2D_{p,2}\alpha_u}{4D_{p,2}-D_{p,1}}\right)^2(D_{p,2}-D_{p,1}) \tag{6.35}$$

$$r_{t,1}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{D_{p,1}\alpha_l}{2}\frac{D_{p,2}(\alpha_u-2\alpha_l)-D_{p,1}\Delta\alpha}{D_{p,2}-D_{p,1}} \tag{6.36}$$

$$r_{t,2}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{1}{4}\frac{(D_{p,2}\alpha_u-D_{p,1}\Delta\alpha)^2}{D_{p,2}-D_{p,1}} \tag{6.37}$$

$$r_{t,1}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{(\alpha_u-2\alpha_l)^2}{9}(D_{p,2}-D_{p,1}) \tag{6.38}$$

$$r_{t,2}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{(2\alpha_u-\alpha_l)^2}{9}(D_{p,2}-D_{p,1}) \tag{6.39}$$

These terms mark the overall problem the decision-makers face. The revenues a platform can realise on transport side depend on the demands (and, thus, prices and quality) on the other market side. Except for the case where demand is exogenous in the transport market (Equations (6.38) and (6.39)) passenger demands enter transport side revenue in an involved manner including reciprocal terms. This means, revenue functions may not be continuous irrespective of the concise configuration of the passenger market side.

To illustrate this issue, Figure 6.4 shows transport revenues for each transport market configuration. The revenues are plotted on the domain of the respective demand in the passenger market. To keep matters simple, all illustrations are based on a covered passenger market.[252] The graphs show that the high quality firm with higher passenger demand generally obtains the lion's share of revenues generated by transport firms. An exception is the case, where both firms have equal demand in the passenger market. Thus, the terms *high* and *low* quality may

[252]Note, for an uncovered transport market given a covered passenger market heterogeneity among transport firms and, thus, their valuation of affiliated passengers needs to exceed the threshold of $\frac{\alpha_u}{\alpha_l} > 4$. This can be seen from the lower boundary of an uncovered transport market in Table 6.9 in combination with the definition of a covered passenger market, where $D_{p,1}+D_{p,2} = \kappa_\theta$.

become obsolete and revenues drop to zero in this Bertrand setting. This can only occur, however, when the transport market is covered.[253]

Furthermore, the graphs show that irrespective of the market situation on transport side the high quality firm has plenty incentive to woo for passengers as this increases revenue on the other market side. In contrast, the low quality firm may or may not benefit from more passengers (in regards to transport revenues). While in an uncovered transport market a plus of passengers increases revenues, in a covered transport market additional passengers intensify price competition. This happens due to a lower degree of differentiation. In a just-covered transport market both effects may balance such that revenues achieve a maximum with regards to passenger demand. These results can also be obtained analytically by the gradient of Equations (6.34) to (6.39).[254]

The ultimate problem for the rival platforms is, however, that demands follow endogenously from prices and quality levels and are therefore no direct decision variables. Thus, the analysis becomes rapidly more involved.

To structure the problem, the two general demand configurations for the passenger market are tackled separately being compartmentalised further by distinguishing the respective market outcomes in the transport market.

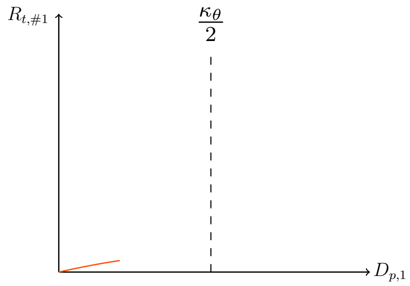
Transport revenues given a covered duopoly passenger market

Given a covered passenger market, demands for the low and high quality platforms are described by:[255]

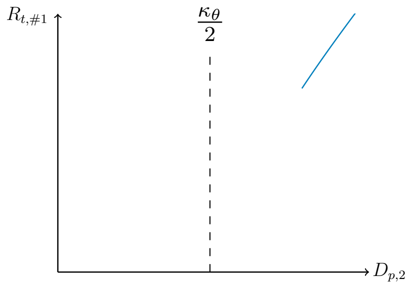
$$D_{p,1}^{CM} = \frac{\kappa\theta}{\Delta\theta}\left(\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} - \theta_l\right) \tag{6.40}$$

$$D_{p,2}^{CM} = \frac{\kappa\theta}{\Delta\theta}\left(\theta_u - \frac{p_{p,2} - p_{p,1}}{s_2 - s_1}\right) \tag{6.41}$$

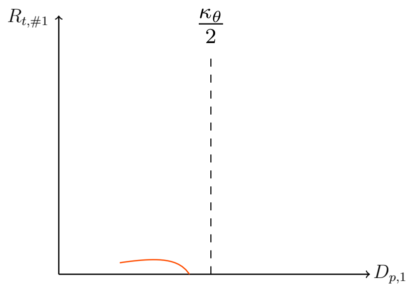
[253] See Figure 6.4 plots (e) and (f).
[254] Note, only for the covered market, these results can be seen without further restrictions.
[255] Cf. Table 6.4.



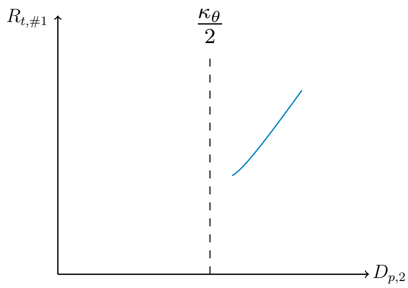
(a) UM: low quality firm



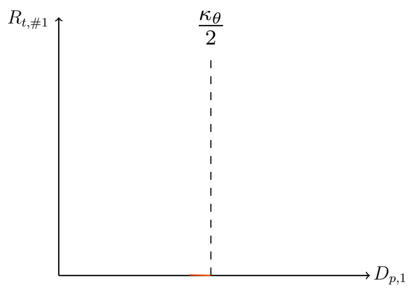
(b) UM: high quality firm



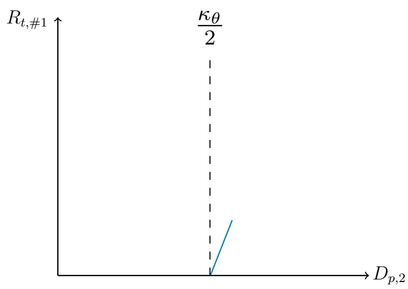
(c) JCM: low quality firm



(d) JCM: high quality firm



(e) CM: low quality firm



(f) CM: high quality firm

Figure 6.4: Reduced duopoly platform revenues on transport side

Parameters $\kappa_\theta = 5000$, $\kappa_\alpha = 10$, $\alpha_u = 5$, $\alpha_l = 1$

Substituting these terms into the transport revenue Equations (6.34) to (6.39) yields:[256]

$$r_{t,1}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\alpha_u^2 \frac{\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \theta_l\right)\left(\theta_u - \frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)}{(4\theta_u - 5\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l)^2}\left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l\right) \quad (6.42)$$

$$r_{t,2}^{UM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\alpha_u^2 \left(\frac{2\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \theta_l\right)}{(4\theta_u - 5\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l)}\right)^2 \left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l\right) \quad (6.43)$$

$$r_{t,1}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{\alpha_l\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_2} - \theta_l\right)}{2}\left(\alpha_u - \frac{\alpha_l\left(2\theta_u - 3\frac{p_{p,2}-p_{p,1}}{s_2-s_2} + \theta_l\right)}{\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_2} + \theta_l}\right) \quad (6.44)$$

$$r_{t,2}^{JCM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{1}{4}\frac{\left(\alpha_u\left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_2} + \theta_l\right) + \alpha_l\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_2} - \theta_l\right)\right)^2}{\left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_2} + \theta_l\right)} \quad (6.45)$$

$$r_{t,1}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{(\alpha_u - 2\alpha_l)^2}{9}\left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l\right) \quad (6.46)$$

$$r_{t,2}^{CM} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{(2\alpha_u - \alpha_l)^2}{9}\left(\theta_u - 2\frac{p_{p,2}-p_{p,1}}{s_2-s_1} + \theta_l\right) \quad (6.47)$$

Equations (6.46) and (6.47) show for a covered transport market that passenger prices enter both revenue terms only in the numerator. The partial derivatives are straight forward: the low quality firm benefits from a higher (passenger) price as this decreases demand in the passenger market and, as a consequence, differentiation of the two platforms in the transport market increases. For the high quality platform the derivative is negative, thus, higher prices lead to revenue cuts.[257] Despite opposing signs the rationale is similar: a lower passenger price increases differentiation in the transport market as passenger demand for the service rises. Given the covered passenger market this is tantamount to a demand shift from the low quality firm to the high quality firm and consequently the two platforms are more differentiated in the transport market.

[256]The same complexity can also be seen in transport side prices once passenger demands are replaced by the terms above. See Appendix F for the resulting reduced prices and further comments.

[257]Note, both partial derivatives are constant and do no longer depend on either price.

For the uncovered and just-covered transport market the revenues contain passenger prices in a more intricate manner. The functions include products and quotients due to both the transport firms' demand functions in Equations (6.28) to (6.31) and transport prices given in Table 6.6. It follows that the marginal effects of a price change is compared to the covered market no longer clear cut.

Keeping in mind that the passenger market is covered ($D_{p,1}^{CM} + D_{p,2}^{CM} = \kappa_\theta$) the first derivative of Equation (6.42) with regards to the first platform's passenger price $p_{p,1}$ depends ultimately on the demand configuration in the passenger market. As long as the market shares in the passenger market are rather unevenly distributed, platform 1 will decrease the revenue generated in an uncovered transport market by raising $p_{p,1}$. In case of a low difference in market shares the same rationale as in the covered transport market applies. This means, the low quality platform has an incentive to increase its price to passengers which will lead to more differentiation between platforms. This alternation of the derivative's sign depends solely on the division of passenger demand. As long as the low quality firm's market share is less than roughly one third of total demand, its revenue does not rise as it decides to increase its price.[258] The rationale for the high quality firm is again rather simple: the platform has no incentive to increase passenger prices (with regards to transport revenues) as this reduces differentiation and, thereby, revenues.[259]

In the just-covered transport market the analysis of the revenue functions' derivatives shows that the effects are mostly similar to the uncovered transport market. However, in this case the exact characteristics of transport firms in terms of their potential to monetise passenger participation (α) plays a direct role. That means, depending the boundaries of α and the resulting demand partitioning, both platforms may have incentives to lower or raise prices to passengers. The rationale

[258] At this point it must be noted that the conditions in Table 4.2 still hold. The example in Figure 6.4 (a) illustrates the case where the derivative is inevitably negative as market shares have to be strongly heterogeneous.

[259] Note, the partial derivative of Equation (6.42) contains both negative and positive terms. However, the positive terms due to the inverse dependence of passenger demand are dominated by the negative terms. Therefore, the sign of these partial derivatives are unambiguously negative. Formally, this can be shown by looking at the roots of the derivative: there are two roots that can be stated in terms of passenger demands. However, within the valid domain the derivative is always lower than zero for the high quality platform.

for both is as follows: when differentiation on the transport market is low which is tantamount to rather similar demands in the passenger market the platforms have incentives to change prices. That means the platform with more demand will reduce prices and its competitor will increase prices. However, once differentiation is large enough the low quality platform has no incentive to increase prices any further. Consequently, in a position with too low demand in the passenger market, a low quality platform will also decrease prices in order to increase market share. However, these considerations all require the conditions from Table 4.2 to hold. As a consequence, in too skewed passenger demand constellations, the transport market may fail to be covered at all and the platforms need to fall back to the results of the uncovered market above.

The effects described can be seen in Figure 6.4, despite the graphs' denomination in demands instead of prices, since higher passenger prices inevitably lead to lower demands for either platform.

The intricacy of these revenue functions and their derivatives in the uncovered and just-covered transport market makes further analyses with regards to optimal passenger prices and in sequence optimal quality choices cumbersome and lengthy, such that interpretations become hard due to the number of dependencies. Nevertheless, the approach to obtain such prices and quality values is described below for all three cases.

The objective functions for the platforms at this stage are:

$$\Pi_1 = \frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1}-\theta_l\right)p_{p,1}+r_{t,1}-c_1 \tag{6.48}$$

$$\Pi_2 = \frac{\kappa_\theta}{\Delta\theta}\left(\theta_u-\frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)p_{p,2}+r_{t,2}-c_2 \tag{6.49}$$

Transport revenues given an uncovered duopoly passenger market

Accordingly, the demand for the even more intriguing uncovered passenger market can be inserted into the revenue functions and profit functions. The passenger demands in this uncovered market are again given by Table 6.4 as:

$$
\begin{aligned}
D^{UM}_{p,1} &= \frac{\kappa\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1}-\frac{p_{p,1}}{s_1}\right)\\
D^{UM}_{p,2} &= \frac{\kappa\theta}{\Delta\theta}\left(\theta_u-\frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)
\end{aligned}
$$

Similarly to the covered market case, it makes sense to evaluate the effects of pricing decisions on the revenues obtained by transport firms. These are given by:[260]

$$
r^{UM}_{t,1} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\alpha_u^2\frac{\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1}-\frac{p_{p,1}}{s_1}\right)\left(\theta_u-\frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)}{(4\theta_u-5\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1})^2}\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1}\right) \tag{6.50}
$$

$$
r^{UM}_{t,2} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\alpha_u^2\left(\frac{2\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1}-\frac{p_{p,1}}{s_1}\right)}{(4\theta_u-5\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1})}\right)^2\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1}\right) \tag{6.51}
$$

$$
r^{JCM}_{t,1} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{\alpha_l\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_2}-\frac{p_{p,1}}{s_1}\right)}{2}\left(\alpha_u-\frac{\alpha_l\left(2\theta_u-3\frac{p_{p,2}-p_{p,1}}{s_2-s_2}+\frac{p_{p,1}}{s_1}\right)}{\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_2}+\frac{p_{p,1}}{s_1}}\right) \tag{6.52}
$$

$$
r^{JCM}_{t,2} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{1}{4}\frac{\left(\alpha_u\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_2}+\frac{p_{p,1}}{s_1}\right)+\alpha_l\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_2}-\frac{p_{p,1}}{s_1}\right)\right)^2}{\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_2}+\frac{p_{p,1}}{s_1}\right)} \tag{6.53}
$$

$$
r^{CM}_{t,1} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{(\alpha_u-2\alpha_l)^2}{9}\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1}\right) \tag{6.54}
$$

$$
r^{CM}_{t,2} = \frac{\kappa_\alpha}{\Delta\alpha}\frac{\kappa_\theta}{\Delta\theta}\frac{(2\alpha_u-\alpha_l)^2}{9}\left(\theta_u-2\frac{p_{p,2}-p_{p,1}}{s_2-s_1}+\frac{p_{p,1}}{s_1}\right) \tag{6.55}
$$

The most simple case is again a covered transport market as it is given by Equations (6.54) and (6.55). Taking the respective derivatives gives the impacts of price changes in the passenger market on revenues in the transport market. For the low quality firm, the derivative is slightly different (in comparison to the covered

[260] At this point, the indices and exponents are similar to the cases above, such that the equations must be distinguished from their counterparts with a covered passenger market by the numbering.

passenger market). With regard to revenue, it is still optimal to raise prices as the derivative is again a constant that is greater than zero. Thus, passengers will partly refrain from the low quality platform and consequently, the platform ensures differentiation in the transport market. In case of the high quality platform, the derivative is exactly similar to the derivative of Equation (6.47). It follows that the high quality platform has ample incentive to lower prices in the passenger market and thereby attains a higher market share in this market. This is then perceived as a higher quality in the transport market.

For the remaining cases the signs of the derivatives are not as straight forward: in the uncovered transport market the derivatives of both firms are non-linear. However, it can be shown that for the high quality platform it is never optimal to raise prices for travellers given that $D_{p,2} > D_{p,1}$ which is exactly the condition for being the high quality firm. Similarly, the competing platform will strive for differentiation and will generally be able to increase its prices. Thereby, $D_{p,1}$ decreases. Depending on the realised difference in passengers' quality, i.e. the expected time reduction offered, the root of the derivative will lie roughly within the following interval $(0, \frac{D_{p,2}}{10})$.[261] Economically speaking, the low quality firm strives to establish large differentiation while not being pushed out of the market at all.

The picture for the just-covered transport market is similar. From the first derivative of the revenue function follows a polynomial, but, due to the restriction, the roots are outside of the domain. Consequently, platform 1 will try to differentiate itself from the high quality competition and therefore will increase its passenger price and, thus, reduce its market share in the very market. For the high quality intermediary, the picture is just vice versa and the platform will decrease passenger prices to offer a larger customer base to transport firms.

[261] The derivative of Equation (6.50) with regard to $p_{p,1}$ can be written in terms of demands and qualities. The corresponding polynomial has exactly three roots given the restrictions that both $D_{p,2} > D_{p,1}$ and $s_2 > s_1$. Two roots are outside the domain, such that only the described root is valid.

The actual problem for the platforms lies, however, in the overall profit functions. In case of an uncovered passenger market these functions are given by:

$$\Pi_1 = \frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \frac{p_{p,1}}{s_1}\right)p_{p,1} + r_{t,1} - c_1$$
$$\Pi_2 = \frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)p_{p,2} + r_{t,2} - c_2$$

Thus, platforms need to consider revenues generated on the other market side as well.

Revenues on passengers' market side

The analyses of platforms' profits includes the revenues on the traveller market. Per se, the analyses are similar to the ones in Chapter 4.2. But after maximising the revenues with regards to their own prices, the marginal revenue of the transport market needs to be taken into account.

Taking these former derivatives of the revenues in the passenger market yields the following three outcomes:[262]

$$\frac{\partial r^{UM}_{p,1}}{\partial p_{p,1}} = p_{p,1}\frac{\kappa_\theta}{\Delta\theta}\left(\frac{-1}{s_2-s_1} - \frac{1}{s_1}\right) + \frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \frac{p_{p,1}}{s_1}\right) \tag{6.56}$$
$$\frac{\partial r^{CM}_{p,1}}{\partial p_{p,1}} = p_{p,1}\frac{\kappa_\theta}{\Delta\theta}\left(\frac{-1}{s_2-s_1}\right) + \frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1} - \theta_l\right) \tag{6.57}$$
$$\frac{\partial r_{p,2}}{\partial p_{p,2}} = p_{p,2}\frac{\kappa_\theta}{\Delta\theta}\left(\frac{-1}{s_2-s_1}\right) + \frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right) \tag{6.58}$$

For all three marginal revenues, the equations are standard:[263] there are two effects. The first one is negative as the consequence of a higher own price leads to lower demand. On the other hand, the second terms give the additional revenue in case the price change would not affect demand. Depending on the actual level of prices either term may dominate and the marginal revenues in the passenger market can

[262]For the high quality platform's revenue it is at this point irrelevant whether the market is covered or not.

[263]Cf. for example Woeckener (2014b, pp. 189–190).

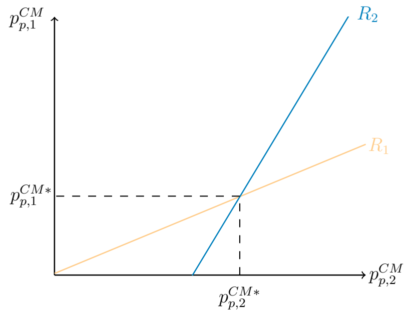


Figure 6.5: Reaction functions given a covered market on either side of two platforms

both be positive or negative. However, these marginal revenues will absolutely decrease as price increases.[264]

Optimal pricing

For now, the price game includes six downstream problems for each combination of market configurations.[265] To conclude this stage, these problems need to be solved for the passenger prices. Since the different market configurations come along with further constraints, the problems need to be tackled by a Kuhn-Tucker approach for each tuple.

For the covered market, the system of equations to be solved consists of the sum of marginal revenues on either market side for both platforms. These are the derivatives of Equations (6.46) and (6.47) and the marginal revenues of the passenger market given by Equations (6.57) and (6.58). The Kuhn-Tucker conditions follow as:

1) Primal feasibility (a): equality constraints (Lagrange): none.[266]

[264] The second derivatives with respect to own prices are always less than zero. Note further that for the passenger market only, marginal revenues increase in the opponent's price. This is again a standard result in differentiated Bertrand competition resulting from the derivative of the marginal revenue with respect to the competitor's price.

[265] These six tuples are couples of either a covered or uncovered passenger market and the respective counterparts in the transport market. However, as it was shown above in the transport market, the just-covered configuration offers a third possibility.

[266] At this point it could make sense to impose a demand criterion $\kappa_\theta = D_{p,1}^{CM} + D_{p,2}^{CM}$. However, the construction of these specific demand functions make a constraint superfluous.

Table 6.10: Price candidates of constraint maximisation (stage 1) in a duopoly setting

Solution	$p_{p,1}^{CM*}$	$p_{p,2}^{CM*}$
#1	$\frac{(s_2-s_1)(\theta_u-2\theta_l)}{3}+\frac{2(7\alpha_l^2-4\alpha_l\alpha_u-2\alpha_u^2)\kappa\alpha}{27\Delta\alpha}$	$\frac{(s_2-s_1)(2\theta_u-\theta_l)}{3}+\frac{2(2\alpha_l^2+4\alpha_l\alpha_u-7\alpha_u^2)\kappa\alpha}{27\Delta\alpha}$
#2	$-\frac{\theta_l}{2}(s_2-s_1)-\frac{\kappa_\alpha}{3\Delta\alpha}\left(\alpha_u^2-\alpha_l^2\right)$	$-\frac{2\theta_u-\theta_l}{2}(s_2-s_1)-\frac{\kappa_\alpha}{3\Delta\alpha}\left(\alpha_u^2-\alpha_l^2\right)$
#3	$\frac{(\theta_u-2\theta_l)(s_2-s_1)}{2}-\frac{\kappa_\alpha}{3}(\alpha_u^2-\alpha_l^2)$	$\frac{\theta_u(s_2-s_1)}{2}-\frac{\kappa_\alpha}{3}(\alpha_u^2-\alpha_l^2)$

2) Primal feasibility (b): inequality constraints:[267]

$$h_1(p_{p,1})=\frac{\kappa_\theta}{\Delta\theta}\left(\theta_l-\frac{p_{p,2}-p_{p,1}}{s_2-s_1}\right)\leq 0$$
$$h_2(p_{p,2})=\frac{\kappa_\theta}{\Delta\theta}\left(\frac{p_{p,2}-p_{p,1}}{s_2-s_1}-\theta_u\right)\leq 0$$

3) Gradient:

$$\nabla\Pi_i(p_{p,1}^*,p_{p,2}^*)-\sum_{i=1}^{4}\mu_i\nabla h_i\stackrel{!}{=}0$$

4) Dual feasibility:

$$\mu_i\geq 0$$

5) Complementary slackness:

$$\mu_i h_i\stackrel{!}{=}0.$$

Tables 6.10 and 6.11 give the solutions to the system of equations spanned by gradient conditions and the complementary slackness conditions.

The unconstrained solution #1 gives an intuitive result by the intersection of the reaction functions that follow the FOCs. Figure 6.5 illustrates this equilibrium. The low quality platform' reaction function has a lower slope than its high quality

[267] These are just the demand functions reformulated such that the constraint matches the formal less-equal description of Kuhn-Tucker problems.

Table 6.11: Lagrange multipliers for the constraint maximisation (stage 1) in a duopoly setting

Solution	μ_1	μ_2
#1	0	0
#2	0	$\frac{(\theta_l-2\theta_u)(s_2-s_1)}{2} - \frac{\kappa_\alpha(5\alpha_u^2-8\alpha_u\alpha_l+5\alpha_l^2)}{9\Delta\alpha}$
#3	$\frac{(2\theta_l-\theta_u)(s_2-s_1)}{2} + \frac{\kappa_\alpha(5\alpha_u^2-8\alpha_u\alpha_l+5\alpha_l^2)}{9\Delta\alpha}$	0

competitor. It follows that the high quality platform can charge a higher price for its service. This pair of equilibrium prices represents a valid interior solution.[268]

For both platforms, equilibrium prices consist of the standard one-sided result from Equations (4.2) and (4.3) plus a term that accounts for the externality passengers create. The given parameter constraints for α_u and α_l that ensure a covered transport market make both of these terms negative. From an economic perspective, this makes sense. Platforms require many passengers to be attractive to transport firms. Thus, they pass the externality through to those who create it. However, the crucial question is whether or to what extend platforms can internalise these network effects?

To evaluate this question, the volume of the discounts have to be compared to the revenues in the transport market. The discounts can be determined by calculating the demands[269] for equilibrium prices:

$$D_{p,1}^{CM*} = D_{p,1}^{CM}(p_{p,1}^{CM*}, p_{p,2}^{CM*})$$
$$D_{p,2}^{CM*} = D_{p,2}^{CM}(p_{p,1}^{CM*}, p_{p,2}^{CM*})$$

[268]Constraining prices to be non-negative leads to a special lower bound. As $p_{p,1}^{CM*} < p_{p,2}^{CM}$, this redounds to $\underline{p}_{p,1}^{CM*} = 0$ where the underline marks the constrained case. Consequently, the high quality firm will play a price of $\underline{p}_{p,2}^{CM*} = \frac{\theta_u}{2}(s_2 - s_1) - \frac{\kappa_\alpha}{\Delta\alpha}(\frac{2\alpha_u - \alpha_l}{3})^2$. This solution will be played when the quality difference $s_2 - s_1$ too small to ensure positive a $p_{p,1}^{CM*}$. Cf. Roger (2017, pp. 211–213) for a different approach to a comparable result.

[269]Demand functions for the passenger market are generally given by Equations (6.40) and (6.41).

The volume of discounts granted to passengers follows from the product of these demands and the respective discount term of the equilibrium price. That is given some reformulations:

$$
\begin{aligned}
&D_{p,1}^{CM*} \cdot \frac{2}{3}\frac{\kappa\alpha}{\Delta\alpha}\left(2\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2 - \left(\frac{2\alpha_u - \alpha_l}{3}\right)^2\right) \\
&D_{p,2}^{CM*} \cdot \frac{2}{3}\frac{\kappa\alpha}{\Delta\alpha}\left(\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2 - 2\left(\frac{2\alpha_u - \alpha_l}{3}\right)^2\right)
\end{aligned}
$$

The revenues of the transport market are given by Equations (6.38) and (6.39). Summing these revenues and the corresponding volumes of discounts up, yields the overall effect on either platform:

$$
\frac{\kappa_\alpha}{\Delta\alpha}\left[\frac{D_{p,1}^{CM*}}{3}\left(\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2 - 2\left(\frac{2\alpha_u - \alpha_l}{3}\right)^2\right) + D_{p,2}^{CM*}\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2\right] \tag{6.59}
$$

$$
\frac{\kappa_\alpha}{\Delta\alpha}\left[\frac{D_{p,2}^{CM*}}{3}\left(2\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2 - \left(\frac{2\alpha_u - \alpha_l}{3}\right)^2\right) - D_{p,1}^{CM*}\left(\frac{\alpha_u - 2\alpha_l}{3}\right)^2\right] \tag{6.60}
$$

For platform 2 Equation (6.60) is negative given the parameters constraints of α_u and α_l for a covered market. This means that the discounts offered to passengers exceed the revenues generated in the transport market. Depending on the actual relation of passenger demands, the low quality platform will also subsidise passengers beyond its revenues on the other market side. This follows from Equation (6.59). While

$$
\frac{D_{p,1}^{CM*}}{D_{p,2}^{CM*}} > \frac{3\left(\alpha_u - 2\alpha_l\right)^2}{2\left(2\alpha_u - \alpha_l\right)^2 - \left(\alpha_u - 2\alpha_l\right)^2}
$$

holds, the subsidy exceeds the revenues of the transport market. Put differently, only for very skewed passenger demand constellations the low quality platform can recoup the discounts granted to passengers by its revenues on the other side.

Summing up this solution, the network externality has a strong impact on competition. Both platforms have to offer discounts to passengers in order to be attractive to transport firms. As these price reductions exceed (in most cases) the revenues on the other market side, competition between the two platforms in such a two-sided market is fiercer than in a one-sided market without demand interdependencies.

Solution candidate #2 cannot represent a valid solution. This is obvious as platform 2 is the quality leader but would have been preempted. The dual feasibility confirms this contradiction: $\mu_2 < 0$.

The last option represents a market where the high quality platform displaces its low quality competitor. This means, the non-negative demand constraint for the low quality platform is binding. This case is further constrained by limits of the covered transport market, such that $\frac{\alpha_u}{\alpha_l} = 2$ by Table 4.2.[270] This condition demotes solution #3 back to the previous section on monopolies.[271]

Mixed equilibria

For the remaining five market configurations the Kuhn-Tucker approach yields no intuitive solutions. This motivates a brief discussion of mixed equilibria.

From Kakutani (1941) and Nash (1950) it is know that there exists an equilibrium when two conditions hold:

- First, the set of strategies available to players is a nonempty, convex, bounded and closed, thus, a compact subset of a finite dimensional vector space.
- And second, the objective function is continuous in the strategies of all players and quasi-concave with respect to a player's strategy.[272]

While the first requirement is fairly easy to establish, continuity and quasi-concavity is a common issue in location models. In Dasgupta and Maskin (1986a)

[270] The result follows, as in the present case qualities correspond to passenger demands. Thus, the condition for a covered market narrows the valid interval down to this point. However, as the analyses in Chapter 4.2 and Table 4.2 show, this limiting point can be assigned to the preempted market, as this point yields no profit for the low quality firm.

[271] Beyond the constraint with regards to transport firms' characteristics (α), dual feasibility demands both the difference in qualities $s_2 - s_1$ as well as heterogeneity of travellers (θ) not to be too developed.

[272] Note that the generalisation to mixed equilibria is due to Glicksberg (1952). For comprehensive summaries cf. Myerson (1991, pp. 136–140) and Mas-Colell et al. (1995, pp. 252–253).

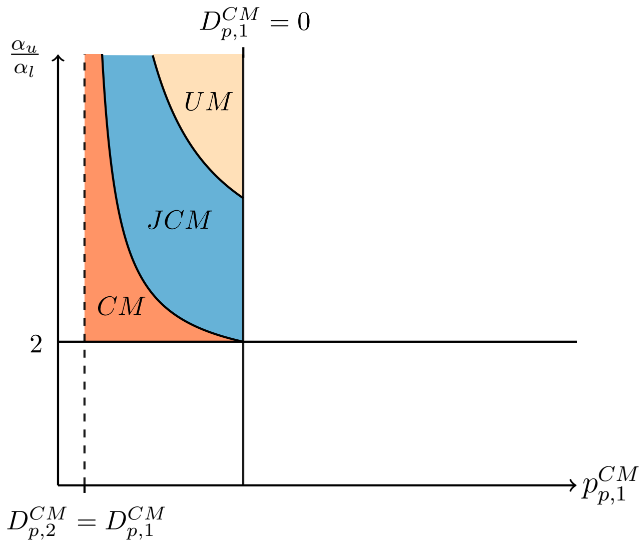


Figure 6.6: Market outcomes according to price boundaries: low quality platform

and their co-paper Dasgupta and Maskin (1986b) the authors show that the continuity assumption can be relaxed so some extend (semi-continuity). In the present cases, where the transport market is either uncovered or just-covered, the objective functions are generally discontinuous. This is due to the passenger demand terms that represent the quality criterion in the transport market. However, by the assumption that the high quality platform will be the one with the higher demand in the passenger market, the discontinuities are outside of the domain of each problem.

The valid domains can be narrowed down further by applying Table 6.9. To illustrate these restrictions, Figures 6.6 and 6.7 show the valid passenger price domains for either platform given some fixed price of the opponent assuming $p_{p,2} > p_{p,1}$ and assuming a covered passenger market. As it has been shown, there is no mixed quality leadership in either market. Thereby, demand $D_{p,2}^{CM}$ must exceed $D_{p,1}^{CM}$. In Figure 6.6 the knife edge case is drawn by the dashed vertical line. This open threshold can be explained by lowering price $p_{p,1}^{CM}$ which induces an increase in demand $D_{p,1}^{CM}$ up to the point that demands are equal. However, this case can be ruled out as it tantamount to Bertrand competition with no differentiation in the transport market. The upper price limit emanates from the demand function having

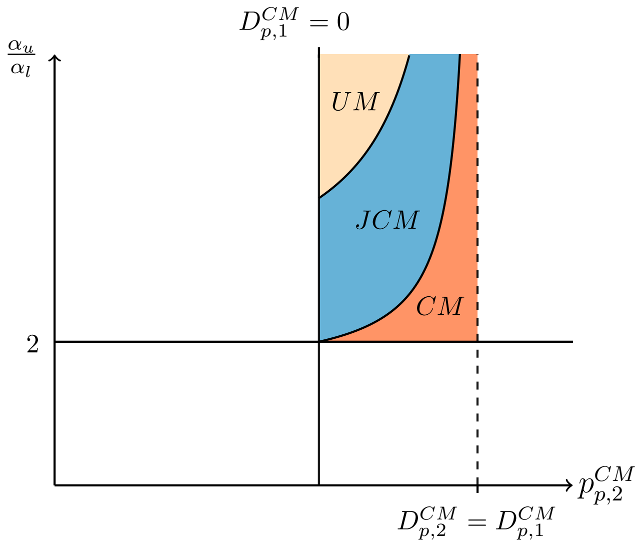


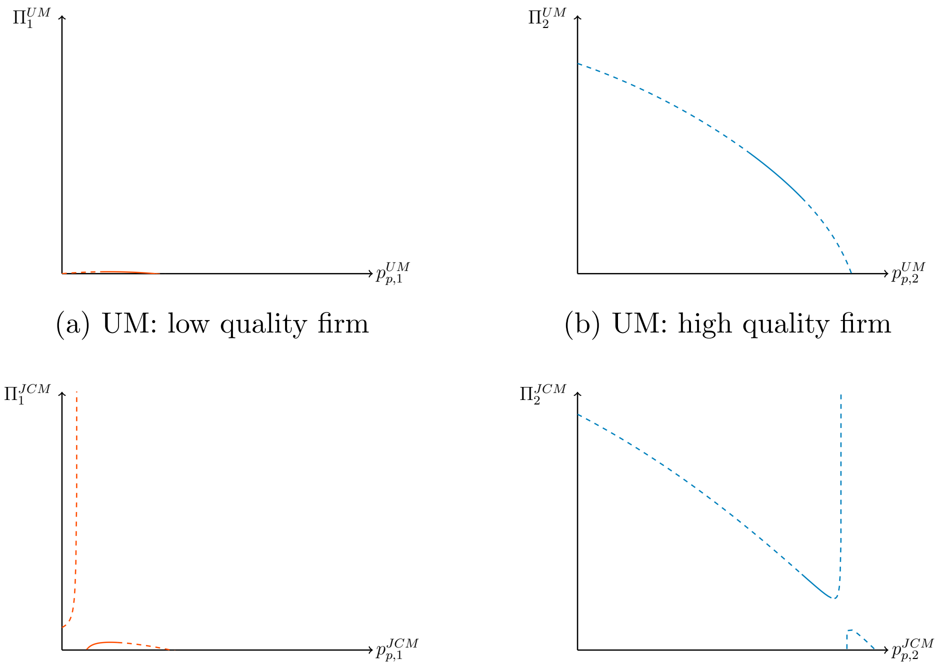
Figure 6.7: Market outcomes according to price boundaries: high quality platform

zero demand for the low quality platform.[273] The limit drawn at $\frac{\alpha_u}{\alpha_l} = 2$ is due to a low degree of heterogeneity in the transport market. Given such characteristics, the market will be pre-empted and covered by a single platform as it was discussed in Chapter 6.1.

For platform 2, Figure 6.7 shows the very same boundaries in terms of $p_{p,2}^{CM}$. The threshold due to transport market characteristics at $\frac{\alpha_u}{\alpha_l} = 2$ applies here as well. Furthermore, market pre-emption occurs when all transport firms are serviced by one platform. This happens when the price-quality relation of the high quality platform leads all transport firms to join this platform. Thereby, the transport market is again covered. The condition is described by $D_{p,1}^{CM} = 0$.[274] At this point it does not make sense for a platform to decrease prices any further. With regard to demand, quality signaling and revenue no advances can be made. The upper bound results from demand cuts due to high prices. At the bound, demands for both platforms are equal and transport firms base their affiliation to a platform

[273]For $D_{p,1}^{CM} = 0$ platform 1 will set $p_{p,1}^{CM} = p_{p,2}^{CM} - (s_2 - s_1)\theta_l$ in accordance to the demand definition in Equation (6.40).

[274]It can easily be shown that given $D_{p,1}^{CM} = 0$ the high quality platform's passenger demand is $D_{p,2}^{CM} = \kappa_\theta$.



(a) UM: low quality firm

(b) UM: high quality firm

(c) JCM: low quality firm

(d) JCM: high quality firm

Figure 6.8: Duopoly profits in the passenger price game for different transport market configurations

only on price. Once again, this can only happen in a situation where the transport market is covered.

Keeping in mind that both α_u and α_l are market parameters and outside the scope of platforms' influence, the valid price domain for each platform satisfies the first condition.[275] With regard to the second condition, the domains lie to the right of the discontinuity for the low quality platform and to the right of the high quality platform. To illustrate this, the graphs in Figure 6.8 provide some examples for both platforms given an uncovered and just-covered transport market.[276] In each graph, the valid domain is highlighted by a continuous line while the dashed lines give the path of the functions outside of this domain. In Graphs 6.8a and 6.8b, the

[275] From a technical perspective it must be noted that in a covered market the boundary towards an pre-empted market is open (cf. Table 6.9). This transfers back into the prices. However, the discussion on vertical differentiation in Chapter 4.2 showed that at the threshold both profits under either regime are equal. Therefore, the boundary can be simply included.

[276] For each market configuration the graphs are based on the pairwise same set of parameters. In addition the implied qualities are set, such that $s_2 > s_1$ and the competitors' prices are defined such that these lie within the valid domain on the other market side.

discontinuities for both profit functions lie outside the printed scope. This marks one extreme as for platform 1 the discontinuity lies at a price lower than zero and for its competitor the discontinuity is at prices that would imply negative profits.

In contrast, the just-covered market displays these asymptotes of the profit functions and supports the claim stated before. Graph 6.8d gives another extreme case including a boundary towards a covered market situation that is close to the local minimum of this profit function right left of the discontinuity. Numerical simulations show that this local minimum is always at a price outside the valid domain, i.e. at a price that is not supported by the just-covered market regime. Overall, Figure 6.8 indicates that the profit functions for both platforms are quasi-concave.

Despite the fact that Graphs 6.8b and 6.8d indicate that a price decrease is always beneficial to the quality leader this is not necessarily true. In fact, increasing heterogeneity among passengers bends the profit curve and allows for a local maximum in the valid domain (for both market situations). However, the relation of profits of the high quality platform in comparison to the low quality platform remains. This means, the high quality platform will always make a greater profit (net of development costs for quality).

To conclude this stage, a dedicated price-equilibrium in pure strategies can only be found in a market where both sides fully affiliate with the platforms, i.e. covered markets in the above manner. This solutions indicates that through the externality platforms are in fierce competition for passengers and that they fail to internalise these network effects. For the remaining cases, the boundaries of these are analysed along the conditions for the existence of mixed equilibria.

Quality choice

Determining the level of quality provided to passengers is the final step in profit maximising for two platforms. As before, both platforms need to develop an optimiser for passengers. Assuming the associated costs depend only on the expected time savings, both firms decisions are based on cost functions given by Equation (6.26).

Similar to the previous step, there exists a pure strategy equilibrium when both passenger and transport market are covered. This equilibrium is determined at first and followed by a brief analysis of the remaining market configurations. Again, in these latter configurations there exist only mixed strategy equilibria for which the general existence conditions are briefly assessed.

Having optimal prices from Table 6.10 for both platforms in the two covered markets profits can be rewritten in terms of qualities:[277]

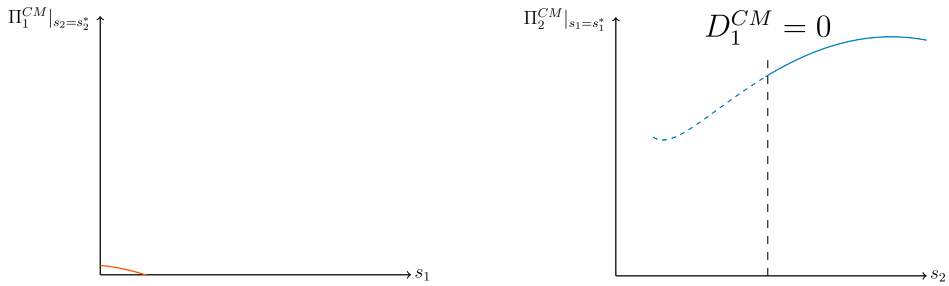
$$\begin{aligned}
\Pi_1^{CM}(s_1,s_2) = & \frac{\kappa_\theta}{9\Delta\theta}\Bigg[(\theta_u-2\theta_l)^2(s_2-s_1) \\
& + \frac{1}{(s_2-s_1)}\left(\frac{\kappa_\alpha}{\Delta\alpha}\frac{2\big((2\alpha_u-\alpha_l)^2+(\alpha_u-2\alpha_l)^2\big)}{3^2}\right)^2 \\
& - \frac{\kappa_\alpha}{\Delta\alpha}\frac{\alpha_u^2(11\theta_u-31\theta_l)+4\alpha_u\alpha_l(\theta_u+7\theta_l)+4\alpha_l^2(4\theta_u+\theta_l)}{3^2}\Bigg] \\
& - \eta s_1^2
\end{aligned} \tag{6.61}$$

$$\begin{aligned}
\Pi_2^{CM}(s_1,s_2) = & \frac{\kappa_\theta}{9\Delta\theta}\Bigg[(2\theta_u-\theta_l)^2(s_2-s_1) \\
& + \frac{1}{(s_2-s_1)}\left(\frac{\kappa_\alpha}{\Delta\alpha}\frac{2\big((2\alpha_u-\alpha_l)^2+(\alpha_u-2\alpha_l)^2\big)}{3^2}\right)^2 \\
& + \frac{\kappa_\alpha}{\Delta\alpha}\frac{4\alpha_u^2(\theta_u+4\theta_l)-4\alpha_u\alpha_l(7\theta_u+\theta_l)+\alpha_l^2(31\theta_u-11\theta_l)}{3^2}\Bigg] \\
& - \eta s_2^2
\end{aligned} \tag{6.62}$$

For both platforms the structure is similar. The reduced profits functions consist of two parts: revenues and costs. The revenue part is subdivided into three terms as enclosed by square brackets in Equations (6.61) and (6.62). While the first terms within the revenue parts are nothing but the one-sided revenues obtained in the passenger market,[278] the second terms give revenues generated in the transport

[277] Despite structural differences, these reduced profit functions can be transformed into the ones Roger (2017, pp. 206–208) derived.

[278] Cf. to the pricing discussion of the plain-vanilla model in Chapter 4.2 and Equations (4.2) and (4.3).



(a) Low quality platform (b) High quality platform

Figure 6.9: Quality equilibrium given covered markets

market. These terms depend inversely on the quality difference $\frac{1}{s_2 - s_1}$. Note that this term is equivalent for both platforms. The remaining terms of the square brackets are adjustments to these revenues for either platform. At this point, it must be emphasised that these individual parts are independent of the actual quality choices, but they are solely determined by market characteristics in terms of the distributions of both α and θ. Furthermore, these latter parts contain the granted discounts to passengers.

Maximising these functions subject to the demand constraints imposed before requires the first derivatives. Due to the squared costs and the inverse terms, the FOCs will be both of order three. Consequently, the same methods as in the monopoly case can be applied to solve these cubic equations.[279] However, only the corner solution with no investments into quality of the low quality platform sustains. This solution is illustrated by the graphs in Figure 6.9. The difference in profits is most striking as the low quality platform makes only a miniscule fraction of profits in comparison to its competitor. The profit function of platform 2 is bounded to the left as is approaches the monopoly case, i.e. the demand of the low quality platform diminishes to zero.[280]

To summarise this case, there exists a market outcome where two platform coexist. In an equilibrium, the low quality firm does not invest in quality and offers its

[279] Cf. Appendix E.

[280] As before in the monopoly case, the cubic equation may have no local maximum to the right term of this demand condition. Therefore, platform 2 may monopolise the market and chooses the lowest attainable quality. Figure 6.9 displays, in contrast, the case were both platforms make positive profits and are active.

Table 6.12: Feasibility of equilibria in vertically differentiated duopoly platform markets

	stage		passenger market covered	passenger market uncovered
transport market	tansport price game	covered	pure	pure
		just-covered	pure	pure
		uncovered	pure	pure
	passenger price game	covered	pure	mixed
		just-covered	mixed	mixed
		uncovered	mixed	mixed
	quality game	covered	pure	mixed
		just-covered	mixed	mixed
		uncovered	mixed	mixed

services only to few customers in terms of market share on either side. As a consequence of the covered market, the high quality platform caters to the lion's share of both passengers and transport firm. This skewness is reflected by the profits, as well.

For the remaining cases, where at least one market is uncovered or just covered, only mixed equilibria can exist. Therefore, the profit functions must comply with the two conditions introduced earlier. Namely, these are compact strategy sets and continuous profit functions (with respect to the strategies). For this game a strategy for either platform consists of of a price-quality tuple given the competitor's choice.

6.2.3 Summary of the duopoly case

To sum up the duopoly setup, Table 6.12 gives a brief overview. Most notable is the fact that for all market configurations pure strategy equilibria only exist in the first stage of the game. In the remaining stages (of price competition in the passenger market and the quality game) only a covered market on both sides yields a pure strategy Nash equilibrium in either stage. Contrasting this, there are only mixed equilibria possible given just-covered or uncovered transport markets, or an uncovered passenger market.

Furthermore, the analysis shows that platforms struggle to internalise network effects. Instead, they pass them through. Thereby, lower prices in the passenger market occur and competition becomes fiercer (in comparison to cases where network effects are absent). In sequence, more passengers take the greater benefit from the high quality platform leading to skewed demands and profits. Figure 6.7 indicates for covered markets on either sides that the high quality firm can decrease its price and, thereby, enforce market exit of the competitor from the transport market. Nevertheless, it was shown that within a narrow parameter range two firms are active in this asymmetric intermediation market.

7 Concluding remarks

Pivotal to this thesis are both the discussion on personal transport intermediation and the analysis of intermediation in the light of quality aspects. Middleman services' strategies, affiliation and pricing behaviour are discussed against the background of the transport setting.

The aims of the first part were to describe the personal transport market and to report the status quo on the digital agenda of German personal transport. Along these remarks, the role of transport associations and new forms of intermediaries have been carved out to motivate the analytical second part. The goal was to assess the possibilities of two-sided market modelling given endogenous platform demand. This means, setting up a framework that can explain why some market participants choose to refrain from joining a platform or making use of its services. In the personal transport field this amounts to the question why some travellers do not inform themselves about alternatives or why for example e-scooter rental services keep to their own sales infrastructure, such as a proprietary app? Ultimately, the purpose of the models presented is to identify the operating levers platforms have to position themselves and maximise their profits.

From a governmental perspective, the role of personal transport is both social and economic. As in Chapter 2.1 described, the EU strives for informing all passengers electronically about personal transport possibilities beyond individual traffic and public transport. Thus, the EU's aim is to inform everyone independent of income about transport possibilities.[281] In addition, making the personal transport market

[281] Feigon and Murphy (2016, p. 26) emphasise on the lack information that represents a barrier for passengers. They promote mobile apps as the means to reduce this barrier. They corroborate this argument by increasing diffusion of mobile technology (in terms of mobile phones) among citizens.

more transparent reduces frictions and targets at making transport systems more efficient.

The topic is of on-going interest to policy makers. For example, regulations and minimum standards on offering both information and payment platforms are to be forged into an official EU regulation by early 2023.[282]

The technological progress of the last twenty years makes new business models possible leading to a more divers landscape of transport modes. This includes car-sharing or rental bikes. The study shows that there is a heterogeneous landscape of transport organisation which is closely linked to the sales channels and information offered to passengers. Beyond these points, the discussion on the German transport regions highlights that there are plenty transport regions with intermediation services beyond the offerings of public transport institutions. Typical features include routing, multimodal optimisation or (mobile) payment. However, the examples of *Teltix*, *DB Touch&Travel* or *moovel* show that establishing a market standard or achieving the critical mass constitutes a barrier on which these firms struggled.

Another factor that attributes to the demise of these intermediaries is the strong market power by the incumbent transport associations who offer, in most regions, the vast majority of personal transport activity (next to individual traffic) as well as regulations imposed on them. As it was described in Chapter 2, many associations offer their own apps which represent competition to private platforms. Taking regulation into account helps to explain why pricing schemes of public transport are to the greatest possible extend static. This means, gross ticket prices for public transport rides are to an utmost degree a fixed datum for all intermediaries as pricing schemes and levels are bound by public transport laws or more precisely to be approved by governmental institutions.[283]

Interpreting public transport as a network industry, similar to for instance, communication or electricity networks, highlights the extend of regulation in personal transport.[284] In these latter markets, the physical networks are open to other

[282] See European Commission (2021).
[283] Cf. § 39 PBefG.
[284] Social aspects to cater to the needs of everyone and subsidies are strong arguments supporting regulation.

market participants. There, taking price regulation as the means of comparison, physical suppliers and intermediaries or service providers have their own pricing authority with differing tariff structures.

The view on the tariff landscape of German public transport shows great complexities and differences.[285] This applies not only on the national level, but within the spatial bounds of associations as well. However, all possible subscription plans and tariffs are set by the transport association. Looking at the limits of associations and towards other forms of transport intermediation, the market for intermediation services is mostly delimited by the spatial bounds of the transport regions. The examples of *DB Navigator*, *Handyticket Deutschland* or the former service *Moovel* illustrate that intermediation services are in competition on different levels.

The models on transport intermediation markets as it is given in Chapter 6 relies on the assumption that all travellers and transport firms could be matched to each other. Therefore, the view in these models with regard to a market definition is linked to smaller geographical entities in form of transport regions. Taking instead larger regions could diminish the network externality passengers exercise on transport firms. Reasons lie in the unlikeliness of a match for spatially distant firms and passengers. However, this view on competition assumes that each intermediary caters to the same subjects and thus regions.

Further, the analyses on the local German personal transport report that in many regions only a transport union or association represents an intermediary offering digital services. With the results from the models in Chapter 6 the tendencies towards monopolisation are confirmed. The models show that only under a few parameter specifications duopoly markets can emerge. In detail, the characteristics of the two user groups determines the market outcome. These characteristics include both heterogeneity within the passenger and transport supply market and the respective market sizes.

As these models only mimic some of the markets' features, it must be emphasised that several assumptions are quite strong. Most prominent, the assumption of

[285]Cf. e.g. Gehrmann (2009).

uniformly distributed valuations of both time and of the network externality.[286] This assumption can be considered a best practice.[287] It offers to a long extend a manageable analytical framework to model the differences between groups. On the other side, it assumes that within groups the agents differ only with respect to a single characteristic. Looking back at the discussion of transport regions in Chapter 2 yields that the singular view on income can be considered to be sufficient for passengers. For transport firms an additional dimension could, however, increase the power of the model as transport firms are of different sizes. These firms offer both different capacities in terms of vehicle sizes and the routes they cater to differ as well. Consequently, the one-dimensional view for transport firms marks a strong assumption.

Another limitation of the presented models is due to the quality interpretation of the network effects. The cross-market interdependence is of a one-directional nature. Adding an endogenous network externality from transport firms towards passengers makes sense as the presence of more transport firms extends the scope for time savings for passengers. Stated differently, the scope of possible connections for passengers increases as more transport firms are affiliated to the intermediary. This restraint has been deliberately chosen to keep the model simple. However, the definition of the quality parameter s as the expected time savings to passengers can include this effect, too. Nevertheless, adding this second network externality for a different application can offer additional insights with regard to pricing and profit maximisation.

To close the discussion, the role of intermediation has been analysed along the example of German personal transport highlighting the relevance of quality. From this discussion a two-sided market approach for was deduced. While the first part represents a snap-shot of the current situation of the German personal transport market and its status of digitalisation, the second part contributes to the thriving literature on platform economics. This part emphasises the tendencies towards monopoly markets and reveals how platforms struggle to internalise network exter-

[286] These valuations are captured by θ and α for passengers and transport firms, respectively.
[287] As has been corroborated by the literature revues in Chapters 4 and 5.

nalities. Instead, the models describe that platforms enforce competitive pricing schemes on the market side from which a cross-market interdependence emanates while pricing on the other market side remains unaffected. Taking these observations together raises questions on antitrust policy in two-sided markets and points to issues left for further research.

Appendix

A Transport regions

This appendix collects additional descriptions to the briefly discussed transport regions in Chapter 2.2. Therefore, it completes the reviews made and contains references on graphs and tables from in this part. Similar to Chapter 2.2, the states, on which additional information is helpful, are separately presented.

A.1 Baden-Württemberg

A.1.1 Regions with mobile sales channels

In the following paragraphs Baden-Württemberg's transport associations that are listed in Table 2.1 and illustrated in Figure 2.4 are adumbrated with regards to their spatial extend. In the same step their mobile services and these of other transport intermediaries available in these areas are assessed.

Two mobile ticketing providers that are active in several associations are named first. These are *DB Navigator* and *HandyTicket Deutschland*. Ticketing through *DB Navigator* is possible in 14 of the 21 transport associations.[288] Exceptions are *Verkehrsverbund Landkreis Tuttlingen (TUTicket)*, *Verkehrsverbund Hegau-Bodensee (VHB)*, *Verkehrsverbund Neckar-Alb-Bodensee (naldo)*, *Verkehrsverbund Rottweil (VVR)*, *Verkehrs-Gemeinschaft Landkreis Freudenstadt (vgf)*, *DING* and *Verkehrsgesellschaft Bäderkreis Calw (VGC)*. *HandyTicket Deutschland* is available in the following regions: *Bodensee-Oberschwaben Verkehrsverbund (bodo)*, *DING*, *VHB*, *Verkehrsverbund Pforzheim-Enzkreis (VPE)* and for *triregio*, i.e. the cooperation area

[288] Cf. Appendix B.

of *Regio Verkehrsverbund Lörrach (RVL)* in and around Lörrach and its partners in France and Switzerland.[289]

Verkehrsverbund Stuttgart

The first founded transport association in Baden-Württemberg is *VVS*. It takes a special role as it emerged from *Stuttgart Region*, a cooperation between districts around Stuttgart coordinating regional planning, promotion of local economic activities and personal transport. State law[290] has granted *Stuttgart Region* authorisation to tender regional train lines and urban railway (S-Bahn) that operate within the regions by itself instead of state government.[291] Today, there are 45 transport providers affiliated to *VVS*.[292]

VVS covers the districts of Böblingen, Esslingen, Göppingen[293], Ludwigsburg, Rems-Murr and the eponymous city Stuttgart. All district and city administrations are among the partner of *VVS*. The *Stuttgart Region*, state, a union of bus companies, *DB* and *Stuttgarter Straßenbahnen (SSB)*, a local transport firm providing bus and tram services, complete the list of partners. The association, *DB* and *SSB* offer multiple smartphone applications for both ticketing and information. While the official *VVS* app that introduced mobile ticketing in 2012 to the association and *SSB's Move* app support only public transport options, *Mobility Stuttgart* app by *DB* includes other private mobility services, such as car- and scooter-sharing or rental bikes. However, this app is not fully integrated as transactions with non-public transport services requires additional apps. In contrast, *ReachNow*[294] includes payments for taxi and car-sharing, but since the union between *Daimler*'s and *BMW*'s mobilty services the respective app no longer support public transport ticketing in *VVS*. *SSB* provides additional apps with best price systems including public transport, car-sharing and taxi services (*VVS BestPreis*) or an app for on-

289 For international rides mobile ticketing is both possible through RVL's *HandyTicket Deutschland* app or the app of *Baselland Transport (BLT)*.
290 In German, namely, "Gesetz über die Errichtung des Verbands Region Stuttgart".
291 See also Section 6Gesetz über den öffentlichen Personennahverkehr in Bayern (BW ÖPNVG).
292 See VVS (2020a).
293 See footnote 49 above.
294 Cf. Appendix B.

demand transport services (*VVS Flex*).[295] The firm also pushes together with VPE a trial of *FAIRTIQ*[296] forward.

Beyond the smartphone-based applications, VVS provides an e-ticket system called *Polygo*. It is based on a smart card. This system is standardised by VDV *and termed eTicket*. The card was introduced to replace paper-based subscription tickets. By the time other mobility services were added. These include eight car-sharing providers, rental bikes and services for motorised individual transport, such as parking and charging.

On the demand side, the association provided around 384 million rides in 2019 as shown in Table 2.1. Putting this number in proportion to 2.5 million inhabitants and to the working population, which was in the same year roughly 1.2 million, yields that approximately 41.6 % of the inhabitants and 88.3 % of the working population conduct on average one daily ride. Assuming that commuters make two rides a day, these numbers have to be reduced by approximately 50 %.[297]

Karlsruher Verkehrsverbund

Lösch (2009, p. 175) summarises the motivation and tasks of KVV in the following way: "As a purely voluntary association of municipalities or *Kommunalverbund*, the *Karlsruher Verkehrsverbund (KVV)* created in 1994 is primarily responsible for transport planning, coordinating transport and operational services, devising and fine-tuning the common-fare system, marketing, and revenue distribution."[298] In addition, the association was found to enhance regional development. Therefore, the efficient urban transport systems in Baden-Baden and Karlsruhe have been merged with the unprofitable rural bus transport. To increase transport supply a hybrid light rail was established. By the time, the connections of this rails system go far beyond the spatial borders of KVV and the idea of such an regional light rail system has become known as the *Karlsruher Modell*. Due to its success, other regions apply the idea to imitate the system. Among these regions the conurba-

[295] These apps are to be considered a field trials for new marketing strategies.
[296] Cf. Appendix B.
[297] See VVS (2020b).
[298] Italics have been added by the author, retrospectively.

tions of Saarbrücken, Kassel or Reutlingen together with Tübingen can be named. Analogously, in France, around Strasbourg, Mulhouse and Nantes, such a system exists or is about to be built.[299]

The association operates in Karlsruhe (city and district), Baden-Baden and Rastatt as well as in Germersheim in Rhineland-Palatinate. Furthermore, tariff acceptance agreements have been established with the district Southwest Wine Route and the city of Landau as well as with *VRN*. In 2019 it catered to roughly 1.4 million residents and carried around 166 million passengers.[300] On the supply side, there are 33 transport firms providing bus, light rail and rail services.

KVV started its mobile phone services with timetables followed by routing. Over the years, several apps have been introduced providing mobile ticketing. At least two of these apps were abandoned by the time.[301] Nowadays, multiple apps include both information services including routing, and ticketing. *KVV.mobil* and *regiomove* are two examples of MaaS platforms that offer services beyond public transport. While the latter includes car-sharing and rental bike, *KVV.mobil* offers scooter and bike rental services and works as the coordinator of *KVV*'s on-demand services. In 2019 and 2020, the association tested a new sales model based on a check-in/check-out system with unlimited public transport rides in the periphery of passengers' homes, called *Home Zone*.[302]

Verkehrsverbund Rhein-Neckar

VRN extends over three states and includes five cities and districts in northern Baden-Württemberg, 17 cities and districts in Rhineland-Palatinate and one district in Hesse.[303] It was founded in 1989 and provides mobility services to three

[299] See Lösch (2009, pp. 175–181), Albtal-Verkehrs-Gesellschaft mbH (2020, pp. 2–6) and Zweckverband Regional-Stadtbahn Neckar-Alb (2020).

[300] See KVV (2020a).

[301] Namely, these are *Ticket2GO* in 2019 and *KVV.ticket* in late 2020. The former provided a special tariff (*E-Tarif*) and a best-price system. The app was also available in for other transport associations in Baden-Württemberg. However, market penetration was low and *KVV* could not recoup costs associated with the service. *KVV.ticket* was replaced but alternative apps named in the text. See e.g. KVV (2019).

[302] See Lösch (2009, pp. 188–189) and KVV (2020b).

[303] Namely, these are Heidelberg and Mannheim, Main-Tauber-Kreis, Neckar-Odenwald-Kreis and Rhein-Neckar-Kreis in Baden-Württemberg, Frankenthal, Landau, Kaiserslautern, Ludwigs-

million inhabitants. According to VRN (2017, pp. 36–37) around 850,000 rides are conducted daily. This corresponds to approximately 15 % of the population using public transport (at two rides a day). These direct transport services are carried out by almost 60 transport firms.[304]

The association offers a diverse supply of digital services including multiple applications addressing different types of customers. As Table 2.2 shows, the first three apps (*myVRN*, *VRN-Ticket* and *rnv/VRN-Ticket*) are universal apps designed for customers frequently using public transport. *DB Navigator*, in contrast, targets on single rides for customers unfamiliar with the services of *VRN*. Two additional applications cater to non-frequent passengers offering special tariffs. While *eTarif* requires travellers to actively sign off, the technologically more advanced *Tickin* gives more comfort as it recognises when the ride ended by itself. All in all, these services contribute to the association's aims on digital services and multimodal transport.[305]

Verkehrsverbund Neckar-Alb-Bodensee

The transport association operating in Reutlingen, Tübingen, Sigmaringen and Zollernalbkreis is called naldo. 53 firms conduct the tendered transport services. These carry nearly 73 million passengers per year or 200,000 per day. In context of approximately 834,000 inhabitants, this means that approximately 12 % use public transport. Since mobile tickets were introduced in 2017, its acceptance grew steadily such that by the end of 2019 the number of mobile sales more than tripled in comparison to 2017. In 2019, steps were taken to extend the scope of tickets sold on their dedicated app. Today, even some subscription tariffs can be bought through the *naldo* app.[306]

hafen am Rhein, Neustadt an der Weinstraße, Pirmasens, Speyer, Worms and Zweibrücken as well as Alzey-Worms (partly), Bad Dürkheim, Donnersbergkreis, Kusel, Rhein-Pfalz-Kreis, Southwest Wine Route (Südliche Weinstraße) and Südwestpfalz in Rhineland-Palatinate. In Hesse the district Bergstraße is part of *VRN*.

304 See Schreiner (2009), VRN (2017) and VRN (2020a).

305 See VRN (2020b) and VRN (2017, pp. 18–21).

306 See naldo (2020a) and naldo (2020b, pp. 10–11).

Regio-Verkehrsverbund Freiburg

Freiburg and the districts Breisgau-Hochschwarzwald and Emmendingen mark the area of *Regio-Verkehrsverbund Freiburg (RVF)*. It was founded in 1994 and is operated and administered by the 18 firms offering transport services themselves. In 2009, mobile ticketing started with *HandyTicket Deutschland*. The system was replaced in 2015 by their own *VAG mobil* app. By 2021 the association offers two apps (*VAG mobil* and *FahrPlan+*) that both provide similar functions. These include information on other services such as car-sharing and rental bikes. The latter can even be rented through the apps after a registration at the operator (*NextBike*).[307]

Despite the fact that mobile ticketing is only responsible for a minor share of all revenues, the number of sales and consequently revenues generated by mobile tickets have sharply increased over last five years from less than 40,000 sales to almost 225,000 tickets in 2019. According to *RVF* the vast majority of these tickets are for single rides. In the future, these apps are the be further extended to provide MaaS beyond rental bikes and public transport. In addition to these apps, *DB Navigator* can be used for ticketing since 2018.[308]

Heidenheimer Tarifverbund

In Heidenheim (district) *Heidenheimer Tarifverbund (htv)* a transport association with six members provides public transport. It offers bus and rail services. In late 2020 mobile ticketing became feasible via *DB Navigator*. For information on routes and live data *htv* refers to *bwegt* app and the corresponding online services.

OstalbMobil

As the name suggests, the association *OstalbMobil* operates in the district Ostalbkreis offering bus, rail and on-demand services for evening hours. More than 20 transport firm carry around 20 million passengers per year. Of these, approximately 50 % are pupils having a corresponding subscription. With the introduction of *bw-*

[307] See RVF (2020a) and RVF (2020b).
[308] See RVF (2020a) and RVF (2020b, p. 13).

tarif, the statewide tariff for rides between two or more transport associations, mobile ticketing became possible for such rides through both *bwegt* app and *DB Navigator*. However, tickets within Ostalbkreis can still only be purchased by traditional means, i.e. at the driver or at ticket machines. In the future, mobile ticketing within the district is to be introduced.[309]

Kreisverkehr Schwäbisch Hall

Kreisverkehr Schwäbisch Hall markets public transport under the brand *Regio Tarif* within the eponymous district. Nine firms provide public transport. In low demand times, on-demand buses that can be ordered by phone complement the line services by the association. For individual transport services, there are two car-sharing providers offering vehicles in the three largest cities of Schwäbisch Hall (district). Since 2006 the association offers a check-in/check-out system called *KolibriCard*. The card offers discounts on single tickets and daily limits. It can be used on bus and rail connections of *Kreisverkehr Schwäbisch Hall* and in *Heilbronner-Hohenloher-Haller Nahverkehr (HNV)*. In October 2019 mobile ticketing was launched through *DB Navigator*.[310]

Heilbronner-Hohenloher-Haller Nahverkehr

In Heilbronn (city and district) and in Hohenlohe *HNV* provides transport services. The more than 580,000 inhabitants within this area generated in 2011 approximately 48.3 million rides. However, the number can be expected to have risen in the mean time. Transport services are provided by 22 transport firms. In addition to public transport, three car-sharing service complement mobility supply.[311]

In 2013, *HNV* launched its check-in/check-out system *eTicketHNV* becoming available within the whole area of *HNV* in 2014. The system is based on the respective standard defined by VDV. Concomitantly, *DB Touch&Travel* was introduced

[309] See OstalbMobil (2019, pp. 11–25).

[310] See KreisVerkehr Schwäbisch Hall GmbH (2018, pp. 29–30 and 69), KreisVerkehr Schwäbisch Hall GmbH (2020a) and KreisVerkehr Schwäbisch Hall GmbH (2020b).

[311] See Stadt Heilbronn, Landkreis Heilbronn and PTV Transport Consult GmbH (2014, pp. 33–34) and HNV (2020a).

for rail traffic. Mobile ticketing started in 2018 with *DB Navigator*. In the future, the association wants to supply passengers with a dedicated app including both information such as routing and ticketing. According to *HNV*'s customer magazine ticketing will be based on *HanseCom*'s *HandyTicket Deutschland*.[312]

Verkehrsverbund Pforzheim-Enzkreis

There are 15 transport firms affiliated with *VPE* handling more than 33 million passengers per year. The association's geographical extend is comprised of the whole district. At the fringes, there are partnerships with the neighbouring associations. Thus, *VPE* tickets are valid for rides to and from the proximate zones of these associations.[313]

The 325,000 inhabitants of the district can purchase tickets through *HandyTicket Deutschland* since 2012.[314] Between 2016 and 2019 the association offered *KVV*'s *ticket2go* app. The mobile ticketing offer has been extended by *DB Navigator* in 2019 and in the future *FAIRTIQ*'s check-in/check-out is to be tested and implemented.[315]

Donau-Iller-Nahverkehrsverbund

In western Baden-Württemberg around Ulm and Biberach as well as in the district of Neu-Ulm (Bavaria), *DING* operates as a transport association administered by both local government and transport firms. The 28 tendered transport firms cater to around 650,000 residents. Transport services include line service and within Neu-Ulm (district) there are several on-demand lines that can be booked online, by phone or via *DING* app. In addition, the app includes ticketing for public transport. Ticketing is based on *HandyTicket Deutschland* and started in 2007. In 2019 the revenues of mobile tickets reached an all-time high of more than 1,410,000 Euro.[316]

[312]See Stadt Heilbronn, Landkreis Heilbronn and PTV Transport Consult GmbH (2014, pp. 98–98) and HNV (2020b).
[313]See VPE (2020a, pp. 14–23).
[314]This works both through the general *HandyTicket Deutschland* app and through *VPE*'s app.
[315]See VPE (2020b) and VPE (2020a, p. 9).
[316]See DING (2021, pp. 14–15).

Bodensee-Oberschwaben Verkehrsverbund

19 bus companies, three railway companies and the three districts Ravensburg, Lindau (Bavaria) and Lake Constance District constitute the transport association *bodo*. It offers mobile ticketing both through *HandyTicket Deutschland* and *DB Navigator*. In addition *bodo* offers a check-in/check-out system called *eCard* and an app for routing and schedules. Per year the association caters to almost 40 million passengers.[317]

Verkehrsverbund Hegau-Bodensee

VHB is the transport association operating in the district around Constance. Similar to other transport associations, it is governed by eight transport firms and the district's administration. *VHB* early partnered with *HandyTicket Deutschland* providing mobile ticketing. Therefore, the association did not pursue *VDV*'s e-ticket initiative. This explains why neither *DB Navigator* nor Baden-Württemberg's *bwegt* app include ticketing in *VHB*. The 285,000 inhabitants, tourist and other public transport users generate 18.8 million passengers per year that are transported by 11 firms.[318]

Southwestern associations

In the south western part of Baden-Württemberg, the five transport associations *Tarifverbund Ortenau (TGO)*, *RVF*, *Verkehrsverbund Schwarzwald-Baar (VSB)*, *RVL* and *Waldshuter Tarifverbund (WTV)* have founded a higher-level associations called *fanta5*. It facilitates transports on routes across more than one of the affiliated associations and offers special tariffs for subscribers and students for the whole *fanta5* region. However, each association governs public transport on its own. This includes their digital services. Thus, there is no dedicated *fanta5*-app.

In Lörrach (district) *RVL* partners with *HandyTicket Deutschland*. Thus, mobile ticketing is available through their app. Together with the adjoining regions in

[317]See bodo (2019, pp. 3–7).
[318]See VHB (no date).

France and Switzerland *RVL* constitutes *triregio*. For international rides mobile ticketing is possible through *RVL*'s *HandyTicket Deutschland* app or the app of *BLT*. Beyond these, *FAIRTIQ* offers a best-price system, including check-in/check-out features and reduced fares.

In Ortenaukreis *TGO* nine transport firms supply public transport services. It offers tickets to neighbouring transport associations and even to Strasbourg. In total, the tariff union carries around 37 million passengers, annually. Mobile ticketing started in 2018 for 430,000 residents via *DB Navigator*. For more mobile information on mobility possibilities *TGO* refers to *bwegt* app and other apps.[319] However, most apps are for information only and provide no ticketing features for rides within the district.[320]

In Schwarzwald-Baar public transport is administered by *VSB*. The association partners with 15 transport firms. Since 2020 mobile ticketing is possible through *DB Navigator*. Transport supply is amended by car-sharing stations in at least five cities.[321]

A.1.2 Regions without mobile sales channels

Verkehrsverbund Landkreis Tuttlingen

In the district of Tuttlingen five transport firms provide public transport services. Together with the neighbouring districts Schwarzwald-Baar and Rottweil the district offers a service called *Ringzug*. It offers rail connections between larger cities. Within Tuttlingen (district) the tariffs of *TUTicket* apply while for outgoing and incoming connections from other associations combination tariffs are charged. The association provides no app and, consequently, mobile ticketing is unavailable. According to the districts public transport plan approximately 8.7 million passengers are carried per year.[322]

[319]These include *HandyTicket fanta5* a local spin-off to *HandyTicket Deutschland*.
[320]See TGO (2019).
[321]See Landratsamt Schwarzwald-Baar-Kreis (2017, pp. 74–75).
[322]See Landratsamt Tuttlingen (2017, p. 1-6).

Verkehrsverbund Rottweil

In 2011 *VVR* transported more than 9 million passengers.[323] The association administers public transport in Rottweil (district) tendering 15 transport firms. It offers online information and routing, but no mobile interface is available and tickets can neither be purchased online though their website nor through other providers such as *DB Navigator* or *HandyTicket Deutschland*.

Verkehrs-Gemeinschaft Landkreis Freudenstadt

15 transport firms constitute *vgf* within Freudenstadt (district). The 118,000 residents have no access to mobile payment systems provided though the transport union *vgf*. For rides to neighbouring associations the apps of these could be used.

Verkehrsgesellschaft Bäderkreis Calw

For Calw (district), a similar structure as in Freudenstadt can be seen. There are 10 bus and rail companies providing public transport. *VGC* does provide information on tariff and route online, but refers to *bwegt* app for mobile information. Ticketing is possible only at ticket machines and within vehicles. The services are amended by on-demand shuttles (*VGCPlus*) and car-sharing stations.

Waldshuter Tarifverbund

The district of Waldshut has its own transport association *WTV*. It is part of *fanta5*[324] facilitating personal transport within the five transport unions in the southwest of Baden-Württemberg. The association allows ticketing through *DB Navigator* and *bwegt* app. In contrast to other associations, it does not cater its own navigation and ticketing app. The association consists of four transport firms that constitute together with the district administration the association's partners.[325] Transport offers are amended by car-sharing stations exist in at least 6 cities.

[323] See Nahverkehrsberatung Südwest (2013, pp. 38–39).
[324] Cf. Chapter 2.2.1.
[325] As of 2020 *WTV* offers a simple calculator on its website to compare car-ownership costs with public transport costs including CO_2 emissions.

A.2 Bavaria

In the following, both the associations operating in Bavaria and the remaining transport regions are assessed with regards to their geographical extend and their digital agenda.

A.2.1 Transport associations

Augsburger Verkehrsverbund

The area of *Augsburger Verkehrsverbund (AVV)* includes the city Augsburg and its district of the same name as well as Aichach-Friedberg (district) and the eastern parts of the district Dillingen (up to Wertingen). Within the city center of Augsburg public transport is free of charge. Another peculiarity is offered by Augsburg's public utility company *Stadtwerke Augsburg (swa)*: Travellers can choose from subscription packages that include car-sharing and rental bikes. Note, that both cars and bikes are provided by *swa* itself. The price structure is designed as a two-part tariff including a base quota for both bike rentals and car-sharing and flat rate for public transport within the inner zones of *AVV*. Rides to other areas of the association's territory require tickets according to *AVV* tariff. To access these integrated mobility services *swa* maintains multiple applications. However, only *swa Mobil-App* includes public transport and the advertised rental services. For all products, ticketing is available within the app. On the association-level, *AVV* provides an additional app that includes information, routing and ticketing for public transport only. Mobile ticketing possibilities in *AVV* are completed by *DB Navigator* and *Meridian BOB BRB — Info & Tickets*.[326]

Landshuter Verkehrsverbund

The transport association *Landshuter Verkehrsverbund (LAVV)* was founded just recently in 2018 to improve public transport. In 2019, a uniform tariff system was established in the district of Landshut. The services include both rail and

[326] See AVV (2020) and swa (2020).

bus systems. Above, these car-sharing is offered by two firms and on-demand shared taxis are available. On *LAVV's* website is Bavaria's routing system included. However, ticketing is presently not available online. Furthermore, the association refers to *Bayern-Fahrplan* and *DB Wohin Du Willst*[327] apps for mobile routing and requesting shared taxis. Both apps lack a payment feature, however, it is to be included in *DB Wohin Du Willst* app.[328]

Münchner Verkehrs- und Tarifverbund

The *MVV* was founded in preparation of the Olympic Games 1972 in 1971. Initially it was an association by the involved transport firms.[329] As a consequence of the Regionalisation Act 1993 the association was restructured in 1996. Since then, the association is governed by state, city and the districts around Munich. It includes both rail systems and bus services. *MVV* includes today the city and district of Munich and beyond these urban areas the districts Dachau, Ebersberg, Erding, Freising, Fürstenfeldbruck and Starnberg. Furthermore, some areas in the districts of Bad Tölz-Wolfratshausen, Miesbach, Roseheim and Weilheim-Schongau are also included in the tariff-area of *MVV* as it is shown in Figure 2.5. As of 2020, the association evaluates an expansion to adjoining districts.[330]

In 1996, *MVV* entered a new era of traveller information. First timetables were sold on disks and later that year *MVV's* website launched. In 2006 and 2007, two ways to access travel data on mobile phones were introduced. These were followed by the *MVV* app in late 2009. After the launch of *Moovel* (cf. Chapter B.6) in Munich, *MVV's* app started mobile ticketing in 2013. The possibilities were extended in 2016 by *DB Navigator* and *Meridian BOB BRB — Info & Tickets* app in 2017. Since recently, the association partners with *Amazon* offering information on *Amazon*'s virtual assistant *Alexa*.[331]

[327] Cf. Appendix B.4
[328] See Zweckverband LAVV (2020).
[329] Cf. Figure 2.3 above.
[330] See MVV (2020b) and MVV (2020a).
[331] See MVV (2020b).

As of 2021 there are 16 car-sharing providers in *MVV*. Most of them are organised as clubs requiring membership.[332] However, with *Share Now* and *Stattauto München*[333] there are providers that are more easily accessible.[334] The supply of alternative transport modes in *MVV* includes, in addition, both rental bikes and electric rental (mini) scooters. These services are partly included into *MVV's* app. However, booking, rental and payment processes require separate dedicated apps. According to Munich's public transport plan, all these processes are to be included into a single app to explicitly avoid the installation of multiple apps.[335]

In October 2020 *MVV* started a pilot with *FAIRTIQ* (cf. Chapter B.7) offering a check-in/check-out system. The system requires *FTQ Lab* app that offers distinguished services in comparison to *FAIRTIQ*'s standard app. These differences are tailored to *MVV* and include monthly discounts.[336]

Regensburger Verkehrsverbund and neighbouring unions

In contrast to the majority of transport associations, *Regensburger Verkehrsverbund (RVV)* is not delimited by districts' borders, but reaches out to larger cities in the adjoining districts of Regensburg (including the city itself) and Schwandorf. Thus, the association's area is star-shaped around Regensburg and includes transport to and from the areas in the neighbouring districts to Cham (partly), Straubing (partly), Neustadt an der Donau, Neumarkt in der Oberpfalz (city) and Sulzbach-Rosenberg (for both see also *VGN*), and Weiden in der Oberpfalz. In Regensburg's latest public transport plan (2010) the association defined both mobile information and ticketing as future aims. By 2016, *RVV* launched a dedicated app and one year

[332] The first club was among these was the *Vaterstettener Auto-Teiler eingetragener Verein — German for registered club (e.V.)*. It started in 1992 with a single *VW Passat* and administers today more than 20 vehicles for its members. It promoted car-sharing in the area and eagerly supported other clubs setting up their car-sharing services. See Diedrichs (2016, pp. 129–131).

[333] Note, the word *Stattauto* is a composition and wordplay that stresses the alternative (German *statt*) to vehicle ownership in cities (German *Stadt*).

[334] These firms only require a short registration and validation of travellers' driving license and no complex club memberships.

[335] See MVV (2020b) and Landeshauptstadt München (2019, pp. 39–40).

[336] See Münchner Verkehrsgesellschaft (MVG) (2020).

later a ticketing feature was added. For these mobile tickets the association offers discounted rates.[337]

Within district of Cham the transport union *Verkehrsgemeinschaft Landkreis Cham (VLC)* administers transport and has set a uniform tariff. However, there are neither online tools for routing or in depth information on schedules nor smartphone applications to simplify travellers choices. The district Straubing-Bogen has a similar structure. Bus services are offered by the local transport union *Verkehrsgemeinschaft Straubinger-Land (VSL)*. Since 2019, the routes between Regensburg and Straubing have been included into *RVV's* tariff area while the remaining parts of the district remains under the auspices of *VSL* and its nine transport partners.[338]

Verkehrsverbund Großraum Nürnberg

Bavaria's largest association is *VGN* in Greater Nuremberg. It includes all districts and independent cities within Middle Franconia[339], the district Kitzingen in Lower Franconia, Bamberg, Bayreuth (both city and district), Haßberge, Forchheim and Lichtenfels in Upper Franconia as well as Neumarkt in der Oberpfalz and Amberg-Sulzbach including Amberg (city) both in Upper Palatinate. However, in Amberg-Sulzbach only rail services are fully integrated in *VGN*, while for bus rides the *VGN* tariff is only applicable when crossing the district's borders.[340]

VGN started to sell tickets online in 2003. Today, *VGN* still provides this service and allows for both instant tickets and other forms including physical tickets sent by mail. In 2006 the association started to partner with *HandyTicket Deutschland* (cf. Chapter B.8) and by 2014 more than 1 million mobile-tickets have been sold. The *Java*-application of *HandyTicket Deutschland* was replaced by a proprietary app for *Android* and *iOS*. Along this introduction the partnership and thereby mobile

[337] See RVV (2020) and plan:mobil and Mathias Schmechtig NahverkehrsConsult (2010, pp. 69 and 292–293).

[338] See RVV (2019).

[339] Namely, these districts are Ansbach, Erlangen-Höchstadt, Fürth, Neustadt (Aisch)-Bad Windsheim, Nürnberger Land, Roth and Weißenburg-Gunzenhausen. The independent cities are Ansbach, Erlangen, Fürth, Nuremberg and Schwabach.

[340] See below and Zweckverbandes Nahverkehr Amberg-Sulzbach and gevas humberg & partner (2016, pp.124–125).

ticketing with *HandyTicket Deutschland* ended. The scope of tickets sold through the app was extended in 2020 and includes both single tickets and subscription tickets. For some tickets, the app provides discounts to customers in comparison to other sales channels. Subscribers are provided with an *VDV-eTicket*,[341] but the app contains the same features as the smart card. Furthermore, *DB Navigator* offers a reduced set of tickets for *VGN* since January 2017.

To enhance intermodal transport, the association aims to integrate other services in their transport services. Therefore, information on general issues and tariffs are to be included to *VGN's* website and app. Similarly, distribution and sales could be integrated into these systems and the *eTicket* could work as a wallet or pre-paid card to pay for all kinds of mobility services. Thus, with a more open portfolio the association will become an intermediary beyond public transport.[342]

Verkehrsunternehmens-Verbund Mainfranken

Verkehrsunternehmens-Verbund Mainfranken (VVM) operates in Würzburg (city and district), districts of Kitzingen and Main-Spessart.[343] It's tariffs are valid on all local bus and train services. Subscribers benefit from reduced prices for car-sharing in Würzburg.[344] The transport association offers information on tariffs and routing on their website and through an app. However, mobile ticketing is unavailable, but is to be considered in the future.[345]

[341] The *eTicket* provided can only be used for subscriptions. Other associations offer more features on their *eTicket*, such as payment (for e.g. car-sharing). In the future more functions are to be added. See Stadt Nürnberg (2019, p. 71).

[342] See Verkehrsgemeinschaft Niederrhein (VGN) (2006), VGN (2014), VGN (2018), VGN (2020) and Stadt Nürnberg (2019, pp. 79–83).

[343] The district of Kitzingen is part of two transport regions, as it belows to *VGN* as well.

[344] These services are provided under the name *scouter*.

[345] See Nahverkehr Würzburg-Mainfranken and Landkreis Main-Spessart (2017, pp. 122–123). Further note that *Würzburger Versorgungs- und Verkehrs-GmbH (WVV)* cooperates with *FAIRTIQ* (cf. Chapter B.7).

Verkehrsverbund Mittelschwaben

The 1996 founded *Verkehrsverbund Mittelschwaben (VVM)*[346] covers the districts of Günzburg and Unterallgäu as well as the city Memmingen. Since 2019 the transport association *VVM* includes rail services on top of traditional bus transport and on-demand buses. In cooperation[347] with the neighbouring transport union *Mobilitätsgesellschaft für den Nahverkehr im Allgäu (mona)* electronic ticketing was introduced in early 2020 after it was announced in 2018. The common *VVM/mona Ticket* app is provided by *eos.uptrade* and allows to purchase both single and long-term tickets for the affiliated line services. *mona* itself operates in Oberallgäu and its enclosed city Kempten, and in Ostallgäu including Kaufbeuren (both since 2017). The union administers bus transport and on-demand taxis.[348]

A.2.2 Further regions with mobile sales channels

In the remaining parts of Bavaria that are not covered by transport associations public transport are either organised by transport unions or by the districts, municipalities or transport firms themselves. To assess the intermediaries and their mobile services, the regions are briefly analysed in the following. The regions and unions with mobile ticketing option provided for all kind of public transport are described in detail, first. Then, the remaining parts are discussed.

In the southern part of the Bavarian Forest, traditional bus services are administered by the district Freyung-Grafenau. Schedules can be accessed online and via *Bayern-Fahrplan*. For the area within and closely around Freyung (city), on-demand shared taxis (*freYfahrt*) are provided by the city in cooperation with *Door2Door*,[349] an intermediary specialised on on-demand services and a local bus company. Rides can be booked by phone or app and are available only five days a week in off-peak hours.[350]

[346] The abbreviation by both associations in *Mainfranken* and *Mittelschwaben* are identical.
[347] This cooperation operates under the name of *Schwabenbund*.
[348] See Landkreis Unterallgäu and Memmingen (2018, pp. 44 and 84), mona (2017) and mona (2020).
[349] Cf. B.5.
[350] See Landratsamt Freyung-Grafenau (2020) and Stadt Freyung (2020).

Tarif Oberpfalz Nord (TON) represents a tariff union in northern Upper Franconia. It covers parts of the districts Amberg-Sulzbach, Tirschenreuth, Neustadt an der Waldnaab and Schwandorf. The local transport unions[351] including 25 bus companies constitute the *TON* tariff union. The union offers a routing app (*TON Tarife*) and informs customers on tariffs on their website. Furthermore, Bavaria's routing app (*Bayern-Fahrplan*) and the app from the adjoining transport associations, namely *RVV* and *VGN*, can be used. In addition to these apps *HandyTicket Deutschland* (cf. B.8) allows mobile ticketing within the *TON* area. The service was introduced in mid 2019. Thus, the region offers both mobile routing and ticketing requiring, however, two separate apps.[352]

In the district and city of Aschaffenburg as well as the district Miltenberg the *Verkehrs- und Tarifgemeinschaft am Bayerischen Untermain (VAB)* operates. It is a transport union founded in 1995 by two transport firms. Four members constitute the union, including two of *DB*'s regional subsidiaries. Thus, the union offers no dedicated app, but information and routing is possible through *DB Navigator*. Since July 2020 mobile ticketing is available within the city of Aschaffenburg through *FAIRTIQ*[353] offering a check-in/be-out system. I.e. travellers need to activate the app to start the ride initiating a counter. When travellers exit the vehicle and terminate the ride the system recognises this and charges customers according to the accrued tariff.[354]

A.2.3 Regions without mobile sales channels

Around Ingolstadt the transport union *Verkehrsgemeinschaft Region Ingolstadt (VGI)* provides mobility services. The tariffs offered are accepted by bus and railway lines. The biggest transport firm *Ingolstädter Verkehrsgesellschaft (INVG)* supplies the region with online information and a proprietary mobile app. This app includes

[351] These are *Verkehrsgemeinschaft Amberg-Sulzbach (VAS), Nahverkehrsgemeinschaft Weiden-Neustadt an der Waldnaab (NWN)* and *Verkehrsgemeinschaft Tirschenreuth.*

[352] See Zweckverbandes Nahverkehr Amberg-Sulzbach and gevas humberg & partner (2016, pp. 181–182 and 291) and Regionalbus Ostbayern (2019).

[353] (Cf. B.7.

[354] See VAB (2020) and e.g. Main-Echo (2020).

information, routing and ticketing. Thus, customers access *INVG's* information services, while *VGI* is on a higher level without customer interaction. The area of *VGI* stretches across the districts surrounding Ingolstadt. These are Eichstätt, Neuburg-Schrobenhausen and Pfaffenhofen.

In Donau-Ries (district), the transport union *Verkehrsgemeinschaft Donau-Ries (VDR)* that is responsible for bus transport in the district does not provide an app. On its website travellers can access information on tariffs and schedules of the lines offered. Rail services by *agilis* and *DB*, and on-demand buses operate outside the union. Thus, rides by these transport providers require separate tickets. Data on connections is deposited at the state agency *Bayern-Fahrplan*. Thus, schedules are accessible through *Bayern-Fahrplan* app or website. The district's administration plans to offer live-data in the future.[355]

The remaining parts of Dillingen (see above) that are outside of *AVV* are organised by the district and local bus companies. Information is distributed through their websites and schedules are retrievable through *Bayern-Fahrplan*.

In Landsberg, *Landsberger Verkehrsgemeinschaft (LVG)* provides bus transportation. The union was founded in 1995 and consist of nine bus companies as members. Currently, mobile information and ticketing is unavailable. However, the union offers online schedules (to bus, train and shared on-demand taxis) and refers to *Bayern Fahrplan* web service as a routing tool.

The parts of Weilheim-Schongau, where *MVV* does not operate, are not organised by a transport union. Mobile information can be accessed in this area via *DB's Wohin Du Willst* and *Bayern Fahrplan* apps. However, the district officially supplies only a booklet with timetables of the lines serviced. Public transport is complemented by a car-sharing club.

Verkehrsgemeinschaft Garmisch-Partenkirchen (VG GAP) unites the services of local transport firms and offers a uniform tariff (cog railway and cable cars excluded) within the district of Garmisch-Partenkirchen. Mobile ticketing is unavailable. In Murnau there exists an on-demand bus shuttle *Omobi*. The service is, however, ex-

[355] See Landkreis Donau-Ries (2015, p. 80).

cluded form *VG GAP*, too. Travellers can request vehicles via app or phone charging a fixed price per ride.

As described above, the northern part of Bad Tölz-Wolfratshausen is covered by *MVV*. In the remaining southern part, bus transport is commissioned by the district without further mobile services. However, *Bayern Fahrplan* provides routing in these areas.

Miesbach offers no uniform tariff as the two bus companies holding concessions are not cooperating in a transport or tariff union. However, most regional bus services are conducted by one of these two firms so that for most travellers one ticket suffices when travelling by bus. Nevertheless, residents enunciated in the latest public transport plan that uniform pricing among all line services would mark a significant improvement. In the same step the population favors an integration of the district into *MVV*. This will be evaluated in the following years followed by a decision not earlier than 2022. Until then mobile services of public transport will be limited and largely be based on *DB's Wohin Du Willst* app.[356]

In Rosenheim (district) planning and assignment of public transport in administered by *Roseheimer Verkehrsgesellschaft (RoVG)*. Its tasks are mainly in defining key parameters of transport and coordinating between transport providers. However, there is neither ticket acceptance between the bus companies themselves nor with rail services. Thus, *RoVG* must be distinguished from tariff and transport unions as an administrative coordinator. Travellers can obtain mobile information through the following apps: *DB Navigator, Bayern Fahrplan* or *Wohin Du Willst*. Live data is partly available. In practice, however, the remote locations and concomitant unstable mobile connections thwart this service. In the near future, the district plans to provide a uniform tariff that could be introduced with the considered expansion of *MVV* to Rosenheim. At the same time, the mobile offerings are to be extended, especially, into two directions: First mobile ticketing is to be introduced and, secondly, other mobility services (including payment features) are to be added, such that intermodal transport is facilitated. As of today, there are

[356]See Landkreis Miesbach and gevas humberg & partner (2019, pp. 40–44 and 138–139).

no large scale rental bikes (except for touristic purposes). A car-sharing company in the city of Rosenheim complements personal transport supply.[357]

In the district of Passau *Verkehrsgesellschaft Landkreis Passau (VLP)* is the transport union under which bus and train services are provided. The line services are supplemented by on-demand buses. Travellers digitally obtain information including a tariff calculator through their website and schedules through *DB Wohin Du Willst* app. Mobile ticketing is, however, not possible.

The adjoining district Rottal-Inn has similar structure with regards to public transport. *Verkehrsgemeinschaft Rottal-Inn (VRGI)* represents the managing institution and is a transport union consisting of seven members from the transport sector (including bus and rail). Information on schedules and tariffs can be found on their website. A mobile application is not available and, consequently, tickets can only be purchased through *VRGI*'s personnel or ticket machines.

Similarly, there is no dedicated mobile application available within Altötting (district). Schedules and routing can be accessed via *Bayern-Fahrplan* and its app, respectively. Public transport is provided by eight bus companies and DB's railway services.[358]

In the Arber region and its corresponding district (Regen) public transport operates under the name *Arberlandverkehr*. It is administered by local government, which set up a tariff structure for the whole district. Thus, *Arberlandverkehr* can be considered as tariff union. Services include bus, rail and on-demand buses. For mobile information *Arberlandverkehr* refers to *DB's Wohin Du Willst* app, which contains schedules and features a routing tool. However, travellers cannot buy tickets online.

Bus service in Deggendorf (district) is supervised by *Verkehrsgemeinschaft Landkreis Deggendorf (VLD)*, the local transport union. It provides detailed information on its website including a tariff calculator. However, travellers can buy these tickets offline only. For routing the union refers to *DB's Wohin Du Willst* app and the

[357] See RoVG and plan:mobil (2019, pp. 125–130 and 226–230).

[358] Altötting's public transport brochure lists nine bus companies. However, *RBO - Regionalbus Ostbayern* is listed twice, as it operates two outpost in the district. See Landratsamt Altötting (2018, pp. 8–9).

information services by *DB*. Rail services and on-demand buses and taxis complete public transport offerings in Deggendorf.

As described above, *RVV* offers a special tariff for connections from and to Straubing. Within Straubing (district) *VSL* provides its bus services and tariffs. There are some lines including the city lines within Straubing (city) that operate outside *VSL*'s tariff system. Furthermore, bus lines to neighbouring district's unions exist and railway services, on-demand shared taxis and taxi services for young adults are additional services within Straubing and are commissioned by the district. Online services include multiple websites with schedules and information on prices. Online and mobile ticketing is, currently, not available.[359]

In Dingolfing-Landau, public transport is commissioned by the district to eight bus companies and *DB* as railway provider for the regional lines. It offers scarce information on the transport possibilities including timetables of the bus lines. Further information can be obtained by calling the person responsible for public transport at the district's administration.[360] In addition, the municipal utility services offer schedules for their four city lines in Dingolfing. Each company charges its own fares. Thus, interchange between lines may require multiple tickets. To solve this ticket-disorder, the district considers founding a tariff union or to impute a price ceiling of fares. Mobile services are not offered and no live data is processed to Bavaria's database.[361]

In Kehlheim (district) public transport is managed by the district's administration. Despite its proximity to Regensburg, Kehlheim is only partly integrated into *RVV*. Thus, *RVV*-tickets are only valid in the eastern parts of the district. On the other side, Mainburg is connected to Munich's *MVV*. In the remaining southern parts the tariff union *Verkehrsgemeinschaft Landkreis Kehlheim (VLK)* sets prices and provides bus services. To complete the confusing situation, there are line services by independent contractors each charging separate prices without interconnection. The district's website provides information on schedules and links

[359] See Landratsamt Straubing-Bogen (2020).

[360] This is explicitly communicated in the district's public transport plan: See Landratsamt Dingolfing-Landau (2019, p. 76).

[361] See Landratsamt Dingolfing-Landau (2019, pp. 24–29, 74–77 and 98–99).

to several routing services. Furthermore, travellers can use *DB's Wohin Du Willst*-app to inform themselves and plan their rides. The apps by *MVV* and *RVV* can be used in the respective areas within Kehlheim, while in the remaining parts tickets are only sold offline. [362]

In Bad Kissingen public transport is organised by the corresponding district. On its public transport website, the district offers information on line services and schedules. References to Bavaria's routing tool and to *DB Wohin Du Willst* app conclude the online offerings.

The district Schweinfurt administers public transport through their transport union *Verkehrsgemeinschaft Schweinfurt (VSW)*. It offers a uniform tariff within the district for all kinds of public transport. Online information is available through the district's website where links lead to routing sites such as *Bayern-Fahrplan*. For the city-lines in Schweinfurt (city) a separate tariff is valid. These services are governed by the city itself and offer self-contained online services. Despite having introduced an electronic ticket for the city-lines, neither for these nor for *VSW*'s services mobile ticketing is available.

In Rhön-Grabfeld, Bavaria's most northern district, bus concessions are assigned by the district. The involved parties constitute *Verkehrsgemeinschaft Röhn-Grabfeld (VRG)*, the local transport union. The tariffs offered also valid on the rail service and for rides to destinations in neighbouring transport unions and its kind, too. As a special service, on-demand buses can be ordered to supplement rail services in times when bus line services are not operating. Online services are limited to information on schedules and tariffs. Thus, no mobile information and ticketing tools are provided or advertised.

Within the limits of Coburg (city and district) public transport offerings are administrated by *Arbeitsgemeinschaft (ARGE) ÖPNV* a team of local government workers form both city and district. A central tool to interact with customers is their website. It provides travellers with information on public transport, such as tariffs and schedules. For more complex routing tasks the website offers links to Bavaria's *Bayern-Fahrplan* routing tool. Beyond that the website offers infor-

[362]See Landratsamt Kelheim (2017).

mation on non-public services, such as the local car-sharing club *Autoparat* and *BlaBlaCar*'s ride sharing platform. In conclusion, the website acts as a mobility information center, but online and mobile payment are unavailable. However, in Coburg's public transport plan it is stated that private sales channels are appreciated leaving room for private developments outside the *ARGE ÖPNV*.[363]

In the neighbouring district Kronach, the digital offerings on public transport are, similarly, limited. On the district's web presence timetables for each route are available for download and a complex table on tariffs is given. Beyond these possibilities, links lead the routing systems of DB and the state Bavaria (*Bayern-Fahrplan*).

A similar structure can be found in the districts to the east and south of Kronach. Specifically, in Hof and Kulmbach information is given on the websites of the district administrations. For the city Hof, the public utility company provides bus services for which, additionally, an interactive routing tool (based on *Google Maps*) together with a *Bayern-Fahrplan* widget are offered.[364] Furthermore, *Door2Door* (cf. B.5) offers the app infrastructure for the on-demand buses (*Hofer Landbus*) in the rural eastern parts of the districts. In Kulmbach, the district offers in a partnership with the district Lichtenfels a mobile app for young adults to book taxis at discounted rates. However, a general mobility tool for all citizens for inter- or multimodal services is presently unavailable. Nevertheless, the district explicates such a service in its mobility outlook for 2030.[365]

Wunsiedel im Fichetelgebirge a transport union provides bus services. The *Verkehrsgemeinschaft Fichtelgebirge (VGF)* was founded in 1986 to combine school and public transport. However, due to high costs and reduced subsidies form the state, the union had to reduce its service levels in 2004. Today, three bus companies constitute the union's administration. The line services within the district are operated by same companies and eight additional contractors. Ticketing is only possible offline and routing is available through *Bayern-Fahrplan*.[366]

[363]See ARGE ÖPNV Stadt und Landkreis Coburg (2015, pp. 30 and 118).
[364]See Stadtwerke Hof (2020).
[365]See Landkreis Kulmbach (2018, p. 228).
[366]See VGF (2020).

The last four districts (Hof, Kulmbach, Kronach and Wunsiedel) have tried to join Nuremberg's *VGN*. However, due to the remoteness and high costs the districts would have had to bear, these efforts failed. In 2018 the districts signed a declaration (Nordost-Oberfranken-Erklärung) addressing state government to support the expansion of *VGN* towards the north-eastern borders of Bavaria. Since *VGN* offers a broad scope of mobile information and payment possibilities, this step would improve the current mobile infrastructure by large.[367]

In Mühldorf (district) *Verkehrsgemeinschaft Landkreis Mühldorf (VLMÜ)*, a transport union partnering with eight transport firms, administers a majority of public transport offers within Mühldorf. The members of the union have agreed on a uniform tariff and coordinated schedules. As all members are bus companies, intermodal transport including both bus and rail requires travellers to purchase two tickets. Through *DB's Wohin Du Willst* app routing and other information are easily accessible for travellers. In the future, an integration into *MVV* is to be considered. Against the background of the digital services offered in Mühldorf, this step would lead to large leap increasing the scope of online services offered. However, the district will instigate the development of extended online services including explicitly ticketing in the next years independent of the decision regarding joining *MVV*.[368]

In Berchtesgadener Land regional bus transport is provided by four companies. The city lines in, for example Bad Reichenhall, however, are carried out by additional bus companies. For all lines, there has been a uniform tariff structure established that organises stops spatially into hexagonal areas. This tariff scheme has just recently been transferred to the neighbouring district Traunstein. Therefore, the two districts offer similar structures to a tariff union. Information on schedules and prices can be obtained via *DB Wohin Du Willst*. Providing extended services, such as a mobility platform for all modes and services, is currently of minor importance to the district. Nevertheless, in the district's mobility concept

[367] See Landkreis Kulmbach (2018, pp. 246–250).
[368] See Landkreises Mühldorf am Inn and gevas humberg & partner (2019, pp. 82, 124–125 and 239–242).

the value of such a platform has been recognised. The two car-sharing stations in Berchtesgadener Land are for example explicit candidates to integrate into such a platform. Furthermore, on-demand services are despite costs a considered instrument to improve public transport.[369]

A.3 Hesse

In the following, the transport service portfolio of *NVV* and *RMV* is adumbrated together with a description of their current digital status with regard to information and payment.[370]

The area supplied by *NVV* is made up of the districts Hersfeld-Rotenburg, Kassel (including city), Schwalm-Eder-Kreis, Waldeck-Frankenberg and Werra-Meißner-Kreis. In addition, the *NVV*-tariff is applied in the adjoining municipality of Staufenberg (Lower Saxony). Mobile ticketing is available in the 1995 founded transport association since 2012. The corresponding app was modernised in 2018 and offers information, routing and tickets. The range of tickets includes both bus and regional rail tickets as well as on-demand hailing services which can be ordered through the app.[371] Furthermore, *DB Navigator* started to offer *NVV*-tickets in early 2021.

Public transport in the metropolitan area around Frankfurt is provided by *RMV*. The transport association covers 15 districts and four administratively independent cities (Darmstadt, Frankfurt, Offenbach and Wiesbaden). The northern districts of Marburg-Biedenkopf, Vogelsbergkreis and Fulda mark the border to *NVV*, while Odenwaldkreis delimits the association to the south. Beyond these areas in Hesse, Mainz (Rhineland-Palatinate) is also part of *RMV*. The association was founded in 1995. At the same time its corresponding tariff structure was launched. It unified its predecessors of 150 transport unions and transport firms. Since then

[369] See Landkreis Berchtesgadener Land (2018, pp. 188–189, 288–289, 375–377, 463–464 and 486–487).

[370] For *VRN* c.f. Chapter 2.2.1 above.

[371] See Verkehrsverbund und Fördergesellschaft Nordhessen and IG Dreieich Bahn (2014, pp. 134–135 and 143).

the tariff system has been slightly changed and agreements to accept tickets from neighbouring associations have been signed to simplify public transport on the fringe of *RMV*.[372]

Among the aims of *RMV* are supplying intermodal connections, mobility services beyond traditional public transport and up-to-date information on all these services. With these ambitions in mind, the digital services offered are indeed extensive: *RMV* started in 2008 to sell mobile tickets and launched an internet shop at the same time. Today, the association offers apps to buy mobile tickets. For customers, who do not have access to the app, a special mobile website offers information in a design adjusted to smartphones.[373] In 2011, the association introduced *VDV*'s *eTicket RheinMain* and initiated *DB*'s *Touch&Travel*-system.[374] By December 2012, *Touch&Travel* was accessible in the entire *RMV* area.[375] The *eTicket RheinMain* is used primarily for subscriptions, but the ticket can also be used for car-sharing and rental bikes. These services are available in multiple cities and are provided by six different transport firms. According to *RMV*'s public transport plan, the *eTicket RheinMain* will support a be-in/be-out system. The underlying technology will recognise when rides start and when they end. Therefore, travellers will only pay for actually performed rides offering maximum convenience. The associations' motives are to increase customer loyalty, lower sales costs and to build a more flexible distribution channel to react on market development.[376]

With plummeting transportation demand, due to the Corona epidemic, the association introduced a pre-paid tariff offering a discount on all rides. As requirements customers are required to register with *RMV* and make a deposit on the pre-paid account. Most app-users and former subscribers will be registered already, thus, only the deposit is required to obtain the discounts.[377]

[372]See RMV (2014, pp. 57).
[373]This service offers only information. This includes routing, live data and ticket prices. Instant purchases are not supported and customers are referred to *RMV*'s proprietary app.
[374]Cf. Chapter B for more information on both systems.
[375]Cf. Appendix B.3 for more information on *Touch&Travel* and its discontinuation in 2016.
[376]See RMV (2014, pp. 61–62, 128–129 and 188-197) and RMV (2020a).
[377]See RMV (2020b).

A.4 Lower Saxony

In Lower Saxony the three groups of transport regions can be distinguished. These are regions that a) provide an administered transport association, b) offer transport services through transport unions and c) do not have structured cooperation between tendered transport firms. In the following these are briefly assessed.

A.4.1 Transport associations

Verkehrsverbund Bremen/Niedersachsen

In Bremen and the districts of Ammerland, Diepholz, Oldenburg (including city), Osterholz, Verden and Wesermarsch the transport association Bremen/Lower Saxony *Verkehrsverbund Bremen/Niedersachsen (VBN)* operates. Beyond these districts, the association provides its services also in parts of Cuxhaven (district), Rotenburg (Wümme) and Nienburg (district). Since 2008 *VBN* offers mobile information on rides and connections. This service has been improved over the years and since 2011 the services were offered by *VBN*'s *Fahrplaner*-app. It supplies information on most connections within Lower Saxony. By 2015, ticketing was introduced to the app. Contrary to the scope of connections given, only tickets within *VBN* or the *Niedersachsen-Tarif*[378] can be purchased through the app. Nevertheless, mobile ticketing is soaring in *VBN* as official numbers show:

- In January 2018 approximately 15,000 mobile tickets were sold.
- In December 2019 approximately 50,000 mobile tickets were sold.

This increase was supplemented by licensing sales to *DB* in mid 2019, i.e. *VBN* tickets became available through *DB-Navigator*, and by a promotion including discounts in September and October 2019.[379]

[378] The *Niedersachsen-Tarif* is a state-wide daily ticket offered by *DB* and was introduced to the app in 2019.

[379] See Zweckverband Verkehrsverbund Bremen/Niedersachsen (2018, p. A-16) and VBN (2020, pp. 43–49 and pp. 62-63).

Großraum-Verkehr Hannover

The *Großraum-Verkehr Hannover (GVH)* is a transport association with integrated bus and rail services. It was founded in 1970 and is responsible for public transport in the metropolitan area around Hanover. Today, Hanover Region (association of the regional conurbation Hanover) and six transport companies constitute *GVH*. Since 2008 *GVH* offers mobile routing and timetables and in 2014 the *GVH App* was amended by mobile ticketing. By August 2018 *DB* was licensed to distribute tickets for *GVH* both online and through *DB-Navigator*. [380]

Beyond these already viable possibilities, Hanover Region puts great emphasis on innovation and further digital services. From the data in the *Mobilität in Deutschland (MiD)* panel in 2016/2017, the region deduced that young adults of whom more than 40 % use public transport change their behaviour towards private motorised transport as they grow older. Among the reasons for this shift the region claims the discontinuation of discounts (e.g. for students), comfort or change of their way of live. To counter this observed migration away from public transport, the region aims to increase customer loyalty through integrated digital services as multimodal transport solutions. In sequence, the region hosted a conference on the future of public transport in Hanover in 2018 that led to the following aims:[381]

- Public transport in Hanover should have better interconnectivity with other modes. Therefore, sharing systems should be integrated into the public transport realm and more bike-parking lots should be built.

- The distribution channels should provide better information and simpler sales systems or mechanism.

- Furthermore, the conference participants enunciated that individual rides will become more important in the future, supporting new services in form of small vehicles or even autonomous vehicles.

[380] See GVH (2018, p. 6), GVH (2020).
[381] See Region Hannover (2020, pp. 59–62).

At the same time, the region recognised that most of these new on-demand services are fairly similar to the on-demand supply offered during off-peak hours. However, the new competitors focus on customer needs and offer attractive and innovative solutions, where cost minimisation comes second. Thus, Hanover strives towards an integrated mobility concept that includes all modes of transport including school transport, innovation sharing services as well as private motorised transport. The tasks of a mobility platform bringing together all parties are to facilitate the processes of information, booking and payment. Thus, all transport-related transactions should be made through the platform. This may also include routing with live data, parking or un-/locking bike-garages. Thereby, the association strives for being a third generation mobility alliance, where integration of all services and the role of a market maker are the cardinal aims.[382]

Verkehrsverbund Region Braunschweig

The cities Braunschweig, Salzgitter and Wolfsburg and the districts of Gifhorn, Goslar, Helmstedt, Peine and Wolfenbüttel form the *Region Braunschweig*. Public transport is administered by *Verkehrsverbund Region Braunschweig (VRB)*, the local transport association. Since November 1998 it offers a zone-based tariff that is valid on all bus and train lines. There exist special contracts that allow travel with public transport to all neighbouring districts. This means, that special tickets sold by *VRB* are accepted, e.g. on vehicles in *GVH* or *Magdeburger Regionalverkehrsverbund (marego)*.[383]

Currently, line services in *VRB* are provided by six railway companies and 16 bus operators. Digital sales channels are available for Braunschweig city lines. These tickets can be bought online or after registration through their app (*BSVG Netz*). Since 2020 mobile ticketing is possible within the whole association via its *VRB-App* that until then offered only routing and information. In the future, *VRB* wants to open its sales system to other provides. Namely, to *DB-Navigator* and to the systems associated with *Niedersachsen Tariff*. Furthermore, they want to integrate

[382] See Region Hannover (2020, pp. 80–86) and cf. Figure 2.3.
[383] See Regionalverband Großraum Braunschweig (2020, pp. 112, 416 and 422–424).

information on car-sharing, on-demand services and rental bikes as well as live data and new tariffs. These tariffs may be other electronic tickets with best-price mechanisms based on check-in/check-out or similar systems.[384]

Hildesheim

ROSA is transport association in the district of Hildesheim. It was just founded in 2019 as a cooperation of the two local bus operators and the rail services of *Nord-WestBahn*. It is therefore among the youngest transport association in Germany. According to Hildesheim's *Green City Plan*, the transport association is eager to expand its services. In the short term, a parking-app is supposed to be introduced helping to reduce traffic associated with parking. Also rental bikes are to be made available for hire in the near future. Both these measures will help to simplify intermodal transport. Other actions to be taken to improve the service offered to customers are cash-less ticketing and mobile ticketing as well as extending the existing on-demand services. In the long-run, a mobility platform is Hildesheims desideratum where consumers can inform and book rides. Information with routing is, currently, only offered on the bus operators' websites.[385]

Southern Lower Saxony

In the districts of Göttingen, Holzminden and Northeim the *Verkehrsverbund Süd-Niedersachen (VSN)* is the transport association administering public transport. It was founded in 1999 and offers a tariff that is both valid on regional trains and all buses. For services to neighbouring tariffs, the association has partnerships that allow travellers to use tickets form their starting point to reach the destinations in the neighbouring area. Since 2017 *VSN* offers a smartphone application that informs passengers on tariffs and routing. Mobile ticketing is unavailable within

[384] See *BSVG*'s website and Regionalverband Großraum Braunschweig (2020, pp. 46–54 and 411–427).
[385] See Landkreis und Stadt Hildesheim (2019, pp. 19–21, 72–73, 146–152, 215–217 and 240).

VSN, except for the *Niedersachsen Ticket*. The services are supplemented by hailed shared taxis.[386]

A.4.2 Transport unions

Verkehrsgemeinschaft Nordost-Niedersachsen

The north western districts adjoining Hamburg are a part of *HVV*.[387] For public transport in Cuxhaven, Rotenburg (Wümme), Heidekreis, Uelzen and Lüchow-Dannenberg, *VNN* represents a transport union.[388] Its main tasks lie in maintaining and improving public transport, defining schedules and tariffs, facilitating cooperation among stakeholders as well as informing passengers.[389] However, *VNN* can be distinguished from a transport association, as it offers no singular tariff. Quite the opposite, there are separate tariffs in most of the relating districts including tariffs to neighbouring transport associations or tariff unions (e.g. *VBN*). Table A.1 summarises the tariffs within *VNN* and shows that only within *HVV* and *VBN* mobile ticketing is possible.

Verkehrsverbund Ems-Jade

The north-western districts and cities of Lower Saxony including East Frisa's districts, Emsland, Friesland and Wilhelmshaven have established a traffic region for public transport (*Verkehrsregions-Nahverkehr Ems-Jade*) in 1997 to administrate public transport with regards to routes and tariffs as well as to facilitate interaction among stakeholders. This includes both local and federal government as well as transport firms. In 2003, these districts (excluding Emsland) founded the transport association *Verkehrsverbund Ems-Jade (VEJ)*. It is responsible to coordinate bus services. Passenger information is available though *VBN*'s *Fahrplaner* application. According to recent public transport plans, the app is supposed to include live data

[386] See Zweckverband Verkehrsverbund Süd-Niedersachsen (2017, pp. 43–44) and VSN (2019, pp. 8–9).
[387] Cf. Chapter 2.2.5.
[388] Despite being covered by *HVV* the three administrative districts Harburg, Lüneburg and Stade are also members of this union.
[389] See VNN (2020).

Table A.1: Tariffs in VNN

Tariff	**Validity**	**Ticketing-App**
HVV-Gemeinschaftstarif	Harburg, Lüneburg, Stade	*HVV-App*
*Stadtverkehrstarif Cuxhaven** (city-tariff)	Cuxhaven (only city)	✗
*VNN-Regionaltarif**	Cuxhaven** (district)	✗
VBN-Tarif	Cuxhaven** (district), Rotenburg** (Wümme)	*FahrPlaner-App****
*ROW-Tarif**	Rotenburg** (Wümme)	✗
*Heidekreistarif**	Heidekreis (except Soltau)	✗
*Stadttarif Soltau** (city-tariff)	Soltau	✗
*Uelzen-Tarif**	Uelzen** (district)	✗
*Wendlandtarif**	Lüchow-Dannenberg	✗

*only bus services, **valid in some parts of the district, ***only for rides within VBN

in the near future. However, there are no explicit ambitions to make discriminated mobile ticketing feasible.[390]

Verkehrsgemeinschaft Osnabrück

Since 1996 public bus transport in Osnabrück (district) is administered by *VOS*. Shortly after the transport union was founded, the individual tariffs of its associated firms were abolished and replaced by a new tariff system for the whole district. In 2003, *VOS* started the *Teltix* mobile ticketing service which was based on calling a number to receive a ticket by SMS.[391] With this system, Osnabrück was among the first cities offering tickets for mobile phones. After the demise of the system in the mid noughties mobile ticketing was unavailable in *VOS* area. Since 2016 the union offers a mobility app *VOSpilot*. Initially, only information on routes and prices were available. In 2017 ticketing was introduced within Onsabrück (city) and in 2020 it became available within the district. The app offers an interface to local car-sharing and, thereby, building a first step to the envisioned mobility

[390] See Stadt Emden (2020, pp. 11–12), Landkreis Leer (2019, pp. 42–43, 73–74 and 89–90), Landkreis Wittmund (2019, pp. 34–36 and 75), Stadt Wilhelmshaven (2019, p. 8 and pp. 61–62). Note, as *Niedersachsen-Tarif* is valid on all public transport lines, a mobile ticket for *VEJ* can be purchased via *Fahrplaner*. Depending on the ride, price may be non-competitive.

[391] Cf. Appendix B.1.

platform for *VOSpilot* to be. This platform is supposed to cater both users of public transport, car-sharing, bike and other rental services as well as individual motorised transport as it offers routing and in the future parking services. For 2020 *VOS* announced a check-in/check-out system based on the app within Osnabrück (city) which allows for a best price option. I.e. travellers' transport usage is traced by the app (entering/leaving a vehicle) and at the end of the day (or week/month) the cheapest combination of tickets is charged. Thereby, *VOS*'s services are to be more convenient to travellers.[392]

Verkehrsgemeinschaft Grafschaft Bentheim

Public transport in County of Bentheim is administered through the transport union Verkehrsgemeinschaft Grafschaft Bentheim (VGB) officially founded in 1996. On their website it offers detailed information on tariffs, routes and schedules. Furthermore, information is provided through *Fahrplaner* and *DB-Navigator* as well.[393]

Verkehrsgemeinschaft Landkreis Vechta

In Vechta (district) bus transport is divided into three pillars: Regular service in rural areas is provided by the local transport union Verkehrsgemeinschaft Landkreis Vechta (VGV), service within Vechta (city) by its city-lines and a on-demand bus service *moobil+* which started in 2013. Today, each service has its own tariffs[394] that makes switching between systems difficult. All three services provide webpages with information on tariffs. Furthermore, VGV and the city-lines provide links to VBN's *Fahrplaner* website for information on routes. *moobil+*, in contrast, has the *Fahrplaner* journey planner included on its webpage. There is also a mobile app to help book rides with *moobil+*, as capacities are limited and travellers are advised to register at least one hour in advance. According to Vechta's current public

[392]See VOS (2020), Manager Magazin (2003), Baumeister (2003), Vorgang (2009, pp. 248–249) and Planungsgesellschaft Nahverkehr Osnabrück (2019, pp. 53–58).
[393]See Landkreis Grafschaft Bentheim (2019, pp. 84–85).
[394]Within the city of Vechta VGV's tickets are to some extend valid on city-line buses and vice versa.

transport plan *moobil+* is to be used as a central mobility platform including car-sharing and e-bike rental services. Despite highlighting that all transport modes and their tariffs shall be listed on the platform, the public transport plan remains silent about ticketing mechanisms.[395]

Verkehrsgemeinschaft Cloppenburg

The Verkehrsgemeinschaft Cloppenburg (VGC) provides bus transportation in the district of Cloppenburg. It is a transport union that was founded in 1998 by local businesses. On their website they provide a widget of VEJ's *Fahrplaner* which helps customers to find connections. Beyond that, connections are displayed on the *Fahrplaner* app. However, the tools lack information on prices, which are only listed as a table on VGC's website. In June 2020 the on-demand bus service in Vechta (district) *moobil+* has expanded and new route in Cloppenburg (district) started operation. As the public transport plan for Vechta (district) stated (c.f. previous paragraph), *moobil+* is supposed to become a mobility platform. This aim has been transferred to Cloppenburg's public transport plan, thus making *moobil+* a public transport portal for both districts.[396]

Verkehrsgesellschaft Landkreis Nienburg

In the district of Nienbung Verkehrsgesellschaft Landkreis Nienburg (VLN) organises bus services. The transport union offers a bus tariff for the whole district and cooperates with all neighbouring public transport unions and associations, such that tickets are accepted and tariffs to the other areas are available. On VBN's *Fahrplaner* app information on routes and prices is given, but ticketing (except for *Niedersachsen Tarif*) is impossible. According to Nienburg's current public

[395] See Landkreis Vechta (2017, pp. 24, 35–37, 91–95 and 130–131), Landkreis Vechta (2020), VGV (2020) and Omnibusbetrieb G. Wilmering (2020).

[396] See Landkreis Cloppenburg (2019, pp. 24, 72–73 and 84), Verkehrsgesellschaft Bäderkreis Calw (VGC) (2020) and Landkreis Vechta (2017, pp. 130–131).

transport plan, non-cash systems shall only be introduced in the long-run after they are established in neighbouring regions.[397] [398]

Verkehrsgemeinschaft Landkreis Schaumburg

In the rural district Schaumburg public bus transportation is supplied by local bus operators. These formed the Verkehrsgemeinschaft Landkreis Schaumburg (VLS), a tariff union. Under the union tickets are valid within the district independet of the line operator. It is planned to introduce GVH's neighbouring reginal tariff within VLS. Beyond traditional line service, there are multiple on-demand busses and taxi services. These operate in the low demand times in the early morning and evening. Information on schedules are available online or can be accessed via *Fahrplaner* or *DB-Navigator*. The union has planned an independent application in the near future providing consulting and information services. However, online ticketing is neither possible on websites affiliated to VLS nor on the apps. [399]

Verkehrsgesellschaft Hameln-Pyrmont

Public transport in Hameln-Pyrmont is administered by the local transport union Verkehrsgesellschaft Hameln-Pyrmont (VHP) that resulted from the fusion of former transport firms in 2019. VHP offers bus transportation under the brand *die Öffis*. On their website they give detailed information on rides, tariffs and they provide a calculator to compare prices of their subscription to automobile usage.[400] Tickets can only be purchased in advance as they are sent by mail. VHP provides the *Meine Öffis*-app that informs customers on schedules and tariffs. As in other rural districts of Lower Saxony, bus and rail transport are separated and tickets are mutually accepted on some routes. Examples are the *Niedersachsen-Tarif* or the so-called *Weserbahn-Kombiticket*. Beyond that, VHP's tariffs are also valid around

[397] At the time when the public transport plan was published, the success of, for example, VBN's mobile ticketing system (c.f. above) was already promulgated.
[398] See Landkreis Nienburg/Weser (2020, pp. 107–108, 135 and 148) and VBN (2020, pp. 88–89).
[399] See Landkreis Schaumburg (2019, pp. 78–79 and 108–110).
[400] See VHP (2020).

Springe and Heyen in the neighbouring districts. In some municipalities on-demand buses complement line-based public transport. [401]

Celle

In the district of Celle, bus transport services are managed since 2002 under the auspices of *CeBus*. In contrast to other transport unions, *CeBus* is a private venture of multiple transport firms plus a minority stake of the district and city of Celle. The union currently operates a website with information on tariffs and timetables. On-demand buses supplement the services provided by line traffic. Tariffs of rail and bus services are incompatible, but the *Niedersachesen Tarif* shall allow mixed rides in the future. According to the districts current public transport plan, the district instigates and supports the development of mobile ticketing solutions.[402] Mobile information and routing is, however, possible through VBN's *Fahrplaner*.

A.4.3 Remaining regions

Emsland

In Emsland there are three transport unions which provide their bus services according the areas of the old districts before the local government reorganisation in 1977. In detail, these are *Busverkehr Emsland-Mitte/Nord* in the northern part of Emsland, *Tarifgemeinschaft Emsland-Mitte/Nord* around Meppen and *Verkehrsgemeinschaft Emsland-Süd* around Lingen. Non of the three offers live data of mobile ticketing. Only *Busverkehr Emsland-Mitte/Nord* and *Verkehrsgemeinschaft Emsland-Süd* offer internet-based schedules on their routes. As VBN's *Fahrplaner* app also provides information on most routes in Lower Saxony, timetables and mobile route planning is feasible through the app.[403]

[401] See Landkreis Hameln-Pyrmont (2018, pp. 57–58 and 88).
[402] See PROZIV Verkehrs- und Regionalplaner (2019, pp. 7, 105, 119–122).
[403] See Landkreis Emsland (2020, pp. 99–105), Busverkehr Emsland-Mitte/Nord (2020) and Verkehrsgemeinschaft Emsland-Süd (2020). As with VEJ the *Niersachsen-Tarif* offers a possibility for mobile tickets.

Islands

Beyond these tariff and transport unions, there are scheduled services to and on the North Sea island as well as along the coastline. These include ferries and island railways (on Borkum, Langeoog and Wangerooge). All these services offer online schedules, but no app-based ticketing.[404]

A.5 Mecklenburg-Vorpommern

This appendix summarises the transport regions that the state Mecklenburg-Vorpommern offers beyond those described in Chapter 2.2.8.

Ludwigslust-Parchim

The district Ludwigslust-Parchim operates its own bus firm. Together with three smaller bus companies it provides bus and on-demand services within the district and in Amt Neuhaus in Lower Saxony (Lüneburg). On their website they inform on tariffs and refer to Mecklenburg-Vorpommern's routing site. Online sales are not offered.

Mecklenburgische Seenplatte

Public bus transportation in Mecklenburgische Seenplatte (district) is provided by *Mecklenburg-Vorpommersche-Verkehrsgesellschaft mbH* offering neither mobile payment options nor their own routing tools. In Vorpommern-Greifswald public bus transport is administered by Verkehrsgesellschaft Vorpommern-Greifswald mbH (VVG). Besides traditional line service, it offers on-demand buses (*Ilse-Bus*) in some parts of the district. For information on routes, it offers both links several online routing-tools (e.g. *Fahrplanauskunft-MV*) and it provides the *VVG live* app. Tickets can, however, only be purchased offline.

[404] The Wangerooge Island Railways together with the complementary ferry is operated by DB, but tickets are unavailable through *DB-Navigator*.

Vorpommern-Rügen

In Vorpommern-Rügen Verkehrsgesellschaft Vorpommern-Rügen mbH (VVR) is the company managing and providing bus services. According to their website tickets can be purchased in advance online. As these tickets are sent by mail, instant ticketing through mobile channels is nevertheless impossible.

A.6 Rhineland-Palatinate

More details in comparison to Chapter 2.2.10 on the transport associations in Rhineland-Palatinate are presented below. Here, both the spatial extend is described along further information with a focus on digital services provided to travellers.

Verkehrsverbund Rhein-Mosel

In north-eastern Rheinland-Palatinate the districts Altenkirchen, Westerwaldkreis, Neuwied, Rhein-Lahn-Kreis, Mayen-Koblenz, Ahrweiler, Cochem-Zell, Rhein-Hunsrück-Kreis and Koblenz (city) constitute the area of *Verkehrsverbund Rhein-Mosel (VRM)*. The association was founded in 2002 and cooperates with 41 transport firms. These provide bus and rail line services. Other types of mobility services are not included into the association. On the demand side, there live around 1,259,000 residents in the districts and cities of *VRM* generating together with tourists and in-commuter more than 114 million rides.[405]

Since 2014 schedules can be accessed via *VRM Fahrplan* app, which includes a routing tool to find the connections needed to get to a destination. Mobile ticketing is excluded from this app, but with *DB Navigator* it is possible for a subset of tickets. This service started in mid 2018.[406]

[405]See VRM (2020, pp. 16–24).
[406]See VRM (2015, p. 11) and VRM (2019, p. 7).

Verkehrsverbund Region Trier

In Trier and its adjacent districts public transport is provided by *Verkehrsverbund Region Trier (VRT)*. The transport association was founded in 2001 by both public authorities and transport firms. After restructuring in 2018, the association is now a subsidiary of the districts and the municipalities it caters to.[407] Thus, 21 private ventures providing transport services are no longer vertically integrated with the association but tendered partners. These carry around 24.3 million passengers per year.[408]

In *VRT* tickets can be purchased online through their website or through the dedicated *VRT Fahrplan* app. However, both sales channels offer only a reduced set of tickets in comparison to ticketing at VRT's offices. Furthermore, passengers can access ticket via *DB Navigator*. The transport association refers to two car-sharing companies on their website and to the *Bürgerbusse* mentioned above. None of these services is integrated into *VRT*'s sales channels and applications.

Rhein-Nahe Verkehrsverbund

Rhein-Nahe Verkehrsverbund (RNN) was founded in 1999 and covers the area of the districts Birkenfeld, Bad Kreuznach and Mainz-Bingen. Also the city of Mainz and the remaining parts of Alzey-Worms (district) that are not part of *VRN* belong to the primary area of *RNN*. Due to its proximity to Frankfurt and Wiesbaden, a contract on ticket acceptance was signed allowing rides into *RMV* and back with a single ticket. This arrangement was introduced in 2002 followed by a similar agreement with *VRN* to Worms in 2007. With the *RNN Companion* app and the *VRT Fahrplan* app there exist two apps that provide information on routing on *IOS* and *Android*, respectively. The association has announced new apps for both mobile operating systems. Until then, *DB Navigator* provides information and mobile ticketing for a reduced set of tickets. In addition, tickets can also be bought online, requiring a printout.[409]

[407] These are Bernkastel-Wittlich, Efielkreis Bitburg-Prüm, Trier, Trier-Saarburg and Vulkaneifel.
[408] See VRT (2020) and VRT (no date).
[409] See RNN (2020a), RNN (2020b) and RNN (2020c).

The association's mobility services by 14 transport firms are supplemented by private car-sharing and rental bikes. Neither of these is integrated into the mobile services of *RNN*.

A.7 Saxony

This appendix gives additional information to the transport associations in Saxony. Each association is discussed separately.

Mitteldeutsche Verkehrsverbund

MDV was founded in 1998. It covers the districts of North Saxony and Leipzig (including the city). In addition, it connects Saxony to the adjoining districts in Saxony-Anhalt including the metropolitan area around Halle (Saale), and to the district of Altenburger Land in Thuringia.[410]

With regards to mobile ticketing, MDV offered the so called *easy.GO*-app, which provided the possibility to purchase a limited scope of the association's tariffs. Thus, ticketing was generally available for all connections offered by members of the association. However, subscriptions and other (second or third degree) price differentiated tariffs were unavailable on *easy.GO*. The app allowed routing within the association's territory and was developed and maintained by *HaCon GmbH*.[411] In 2020 the app was retired and replaced by *MOOVEME*. Additionally, further options for mobile ticketing have become available to travellers through *DB Navigator* and *LeipzigMOVE*. The latter is a MaaS provider and includes both *Nextbike* and *DB Flinkster* as bike and car sharing providers, respectively. Beyond that, it offers a two-part tariff. This tariff is advertised under the brand *MOVE+* and consists of a monthly fee and discounted *MDV*-tickets. In addition to these services, the check-in/check-out system by *FAIRTIQ* can be used within the limits Halle (Saxony-Anhalt).

[410] See also 2.2.13 and 2.2.15.

[411] See also Zweckverband für den Nahverkehrsraum Leipzig (ZVNL) (2017, pp. 36–41).

Furthermore, a service for frequent travellers, i.e. those with monthly or annual tickets, is provided. These benefit from discounts on both membership and rental fees at *teilAuto* car-sharing. To use this service, however, the corresponding app is needed, as *easy.Go* offers only information and services on public transport.

Verkehrsverbund Mittelsachsen

In the districts Mittelsachsen, Chemnitz, Zwickau and Erzgebirgskreis public transport is governed by Verkehrsverbund Mittelsachsen (VMS). Mobile ticketing is available through *HandyTicket Deutschland* and its ticketing scope is limited to public transport, only. The association's offers beyond traditional line service include a route-based on-demand taxi service that is available during nighttime. According to the region's public transport plan, private services that may enter the market for personal transport and concomitantly represent a substitute for the association's services will neither be integrated into the association nor its information tools.[412] Therefore, the region takes a staunch position for the publicly mediated second generation of associations maintaining the monopoly status of the intermediary.

Verkehrsverbund Oberelbe

Verkehrsverbund Oberelbe (VVO) is comprised of the four districts Meißen, Dresden, Sächsische Schweiz-Osterzgebirge and Bautzen. For the latter, however, only the northern and western part are integrated into VVO while the remaining part belongs to Zweckverband Verkehrsverbund Oberlausitz-Niederschlesien (ZVON). The 1998 founded association offers at least seven ways to purchase mobile tickets. These include the dedicated *VVO Mobil*-app, *DVB mobil*-app, *HandyTicket Deutschland*-app, *Mobi*-app and the *DB Navigator* as app-based solutions. Above, tickets can be purchased via `www.vvo-mobil.de` and `m.dvb.de` requiring only a web browser and registration for *HandyTicket Deutschland*. A registration on *HandyTicket Deutschland* is mandatory for *VVO Mobil*-app, *DVB mobil*-app and obviously for *HandyTicket Deutschland*-app to use ticketing, as well. This dependence indicates the role

[412] See VMS (2016, pp. 37–64).

of the latter more universal app, which provides the underlying technology for the local apps.[413] A further reason for the dominant position of *HandyTicket Deutschland* is that the region was among the associations that piloted and developed the service.[414]

Verkehrsverbund Vogtland

In the district Vogtlandkreis Verkehrsverbund Vogtland (VVV) is the operating transport association. As in most associations in Saxony, *HandyTicket Deutschland* is offered as a mobile information and ticketing tool. In the major cities Plauen and Reichenbach the application can additionally be used to pay for parking. In Figure 2.13 the transport region is shown by the dark orange area is in the south west.

VVV is responsible for the administration of *ErgoNet*. This is a subordinate association to connect cities and sights from different German states[415] and Karlovy Vary Region in the western part of Czech Republic and offering a separate tariff. The simple tariff structure offering only daily tickets (with a discount for additional travellers) for the whole network is oriented towards recreational transport rather than for daily commuting or short distance travelling. As the network is closely affiliated to VVV, tickets are also available through *HandyTicket Deutschland*.

Zweckverband Verkehrsverbund Oberlausitz-Niederschlesien

The ZVON association is responsible for public transport in south-eastern parts of Bautzen and Görlitz (both districts) as depicted by the yellow area at the eastern fringe of Figure 2.13. Besides ZVON tariff there is a partnership with the neighbouring Czech public transport association. This *Euro-Neisse-Tickets* allows for cross-border transport going beyond the districts within Saxony and Liberec (Czech Republic) to the adjoining districts in Poland. To simplify travel, there is an on-

[413] *VVO Mobil*-app and *DVB mobil*-app are meant by local apps.
[414] See VVO (2019, pp. 60–73) and Haase (2009, pp. 258–261)
[415] The service is available in parts of Upper Franconia and Upper Palatinate (both Bavaria), Vogtland and parts of Erzgebirgskreis and Zwickau (Saxony) and Saale-Orla-Kreis, Greiz and Gera (Thuringia).

line application for trip planning (*NEISSE:GO*). For rides in ZVON-area, mobile ticketing is available through *HandyTicket Deutschland* since 2007 offering a 10 % discount on a selection of tickets. *Euro-Neisse-Tickets* are, however, unavailable through *HandyTicket Deutschland*.[416]

A.8 Saxony-Anhalt

In Saxony-Anhalt there are two transport associations. These are *Magdeburger Regionalverkehrsverbund (marego)* and *MDV*[417] highlighted in orange and purple in Figure 2.14, respectively. The latter covers the districts of Anhalt-Bitterfeld, Dessau-Roßlau and Wittenberg (all *MDV-North*[418] highlighted by horizontal dotted lines in Figure 2.14), and Burgenlandkreis, Saalekreis and the city of Halle (Saale).[419]

marego as the name suggests is the transport association in the region around Magdeburg. Besides the city, the districts of Börde, Jerichower Land and Salzlandkreis are comprised by the young association that has just been established in 2010.[420] Currently, there is no MaaS-provider, however, *marego* offers car-sharing and bike rental services by *TeilAuto* and *Stadtwerke Haldensleben*. These services can be accessed by commuters having a so called *ABO-Karte*, i.e. a monthly or annual ticket.

Mobile ticketing is possible through multiple channels: *marego* itself offers a ticket shop on their website allowing to buy tickets for instant and for future rides. Passengers can also buy tickets through *DB Navigator*[421] and before its discontinuation *easy.GO* also offered mobile ticketing. Within the city area of Magdeburg *FAIRTIQ*'s check-in/check-out app can be used offering a best price system. Timetables and information on prices can also be accessed via the *INSA*-app. *INSA* is an ap-

[416] See ZVON (2018, pp. 97–102).

[417] Cf. Chapter 2.2.12.

[418] MDV-North was established on December 15 2019 and covers only rail connections. Bus and tram services are still provided by the local partners *Vetter GmbH* and *Dessauer Verkehrs GmbH*, but according to MDV they are to be integrated in the near future.

[419] For detailed information on *MDV* see 2.2.12.

[420] There are some municipalities beyond these districts that are connected to the association.

[421] In *marego DB Navigator* supports subscriptions, too.

plication available for the whole state of Saxony-Anhalt. *HaCon* provides data on timetables, which is supplemented by information on tariffs for *marego* and *MDV*. On *INSA*'s website they proclaim to make mobile ticketing available in their app in the near future.

The remaining parts that are not supplied by *marego* and *MDV* are organised by local public transport providers. These are: *stendalbus GmbH* in Stendal (District), *Personenverkehrsgesellschaft Altmarkkreis Salzwedel mbH* in the corresponding district, *Harzer Verkehrsbetriebe GmbH* and *Halberstädter Verkehrs-GmbH* in Harz district and in Mansfeld-Südharz bus transport is provided by *Verkehrsgesellschaft Südharz mbH* and its partners. As of 2020, these companies offer no mobile ticketing.

In the future Saxony-Anhalt aims to improve public transport by offering more information and ticketing possibilities to travellers. Besides the *INSA*-app the Nahverkehrsservice Sachsen-Anhalt (NASA) initiated the *Mobilitätsportal Mitteldeutschland*, an online tool to plan rides including modes beyond bus and rail services, such as intermodal travel (Park & Ride or Bike & Ride) as well as car-sharing and bike-sharing. Their self-set aim is to provide the service also outside of Saxony-Anhalt.[422]

[422] See NASA GmbH (2019, pp. 22–23).

B Mobile payment solutions

This appendix gives additional information on the mobile services that facilitate personal transport in Germany. Focus lies on services described in the text above.[423]

B.1 Teltix

The *Teltix* system was first introduced in the end of January 2003 in Osnabrück. It was designed to offer an additional sales channel and to increase comfort while purchasing tickets. Specifically, the ticket was designed to avoid queues, circumventing frustration with broken or soiled ticketing machines simplifying ticket choice and most importantly conducting cash-less payments. It follows that mobile ticketing solution caters predominantly to travellers without subscriptions.

Technologically, the system required an device supporting telephone services and Short Message Service (SMS). The customer had to dial the station's or bus stop's *Teltix* number[424] receiving the ticket almost instantly via acSMS. Thus, the system recognised the customer by his or her phone number and adds the ticket on the associated monthly bill. The data generated on the bill was used to minimise travellers' expenses by a best price mechanism. I.e. monthly, weekly or daily tickets (that include a discount) are charged, if they lead to lower sums than single tickets only or any mixture of the listed ticket categories.[425]

[423]Therefore, this list is not exhaustive.
[424]To make the system more adaptable, an appended digit for the distance or ticket category was considered to be introduced.
[425]See Baumeister (2003, pp. 68–69).

By the time VDV tried to establish a national mobile ticketing system.[426] However, a *Java*-based system was prefered by VDV to *Teltix* due to conflicting interests. In sequence, *Teltix* was introduced in other city such as Cologne and Bonn. However, the firm was sold subsequently and the ticketing system never reached critical mass (both with respect to travellers and supporting regions), and finally vanished.[427]

B.2 DB-Navigator

DB developed *DB-Navigator* along the *cairo - context aware intermodal routing* project supportet by Bundesministerium für Wirtschaft und Energie (BMWi) in 2009. At first, the app was limited to information on rail services on intermodal offerings of *DB*. These included *DB*'s car-sharing service (*Flinkster*) and rental bike service (*Call a Bike*).[428] By 2013 *DB* merged their ticketing appliction with *DB-Navigator* providing information, planning and purchasing from a single source.[429]

B.3 Touch&Travel

Touch&Travel was a check-in/check-out system offered by *DB*. It was introduced in 2007 for long distance rides and discontinued in 2016. During operation the service was also extended to multiple transport associations.

Travellers needed to check-in through a smartphone or sign-in in via a terminal at a station or in a vehicle. Once the destination was reached, the passenger simply checked-out. This mechanism offered a comfortable way for passengers knowing how to get to their destination. For those, paying became a process of a few seconds and included a best-price mechanism if multiple rides were taken during a day. At the same time, the price system was, however, non-transparent, as the

[426] See e.g. Manager Magazin (2003).
[427] Jochen Baumeister, the founder of *Teltix* reclaimed the website and the basic mechanism of the system can still be tested. See `https://www.teltix.de` (last visited 02 October 2020).
[428] See Schelewsky (2013, pp. 311–312).
[429] Cf. Beul-Leusmann et al. (2014) on statistics on user-friendlyness and real life performance.

true cost of travelling became only clear at the end of the month, when travellers were charged for their rides.[430]

Reasons for the demise of the service lie in the low user acceptance and costs of both hardware and maintenance. The technology was continued in Baden-Württemberg with the *Ticket2Go* app, but due to alternatives it was retired in 2019 and finally shut down in 2020.[431] A similar service is nowadays provided by *FAIRTIQ*.[432]

B.4 DB Wohin Du Willst

DB's regional bus carriers developed an app for its services. This app is *Wohin Du Willst* and provides timetables, routes and on-demand services. Above, it informs on regional news. The app is designed to include more on-demand services in rural areas. As of 2021, on-demand buses can be ordered in 16 regions. For the future the developers have announced ticketing possibilities.

B.5 Door2Door

Door2Door is a private venture that consults transport firms, transport unions and associations on mobility. They focus on software solutions to improve services. Among their portfolio are on-demand apps for transport intermediaries. In Germany, they provide these mediation services in seven regions.

B.6 ReachNow

ReachNow is part of the mobility services offered by *BMW* and *Daimler*. It is a MaaS solution that includes multiple modes. For some modes payment is integrated, while for other modes references to dedicated apps that include payment are given.

[430] See IGEB (2007) and Schelewsky (2013, pp. 318–319).
[431] See KVV (2019).
[432] Cf. B.7 below.

Historically, there existed an app by *Daimler* named *moovel* and *BMW*'s *ReachNow*-app. With the merger of the mobility services business units of the two firms in 2019, the branding *moovel* was discontinued and the services of *moovel* and *ReachNow* were consolidated under *ReachNow* branding.

By the time of writing, public transport tickets could only be purchased for *VRR* and *HVV* while its predecessors provided ticketing for at least Berlin, Munich and Stuttgart. For *moovel* the public transport ticketing option was in introduced in late 2012.[433] As the service was established by the two German premium Original Equipment Manufacturers (OEMs), their car-sharing services can be booked through the app. Beyond, it cooperates with taxi services, rental bikes by *nextbike* and electric scooters by *TIER* and *Voi*.

B.7 FAIRTIQ

FAIRTIQ is a new approach to location-based ticketing including a check-in/check-out system. Similar to *Touch & Travel*, the passenger logs into a ride and once terminated the user or the systems automatically logs off, thus it can be classified as a check-in/be-out system. In contrast to *DB*'s service, users only need their mobile phone and vehicles do not require expensive hardware. The drawbacks of this solution are next to privacy issues that only line services can be booked. Thus, the app represents a payment solution for informed travellers.

The service was developed in Switzerland and is presently available[434] in Aschaffenburg, Göttingen, Flensburg, Halle, Magdeburg, Munich, Würzburg, in *RVL*, *VMT* and *VVO*.[435] As of 2020 there are multiple other cities and transport associations that plan to introduce or pilot *FAIRTIQ*'s payment app. Among these are for example *VPE* and *VVS*

[433] See Schelewsky (2013, p. 310).

[434] This includes pilots for a limited number of users. An example is MVV with its *SWIPE + RIDE* project.

[435] For the named cities, only the transport services by the partnering transport firms can be used. This means tickets for the association of these cities are unavailable within the app.

B.8 HandyTicket Deutschland

HandyTicket Deutschland is among the vanguards of mobile ticketing in Germany. In 2002 the first Saxonian transport associations pondered about mobile ticketing. In 2003, a statement of intent to introduce an electronic ticket was signed for public tranport all over Saxony. One year later a *Java* application for mobile phones is put forward to development by multiple transport firms, transport associations from all over Germany and the federation of transport firms *VDV*. In 2007, *HandyTicket Deutschland* launches in 14 cities and the associated transport associations. The application was a success as more than 25,000 tickets were sold during the first year of operation in Dresden's *VVO*, only.[436]

After the pilot ended in 2011 the system was continued and after tendering the system is operated by *HanseCom Public Transport Ticketing Solutions GmbH* until today. During the pilot new regions joined the platform. However, also the first region decided against the service and prematurely existed the trial. With the development of smartphone applications and integration of timetables and ticketing possibilities some larger associations turned their backs on *HandyTicket Deutschland* as their own app proved to be more successful in terms of users.[437] Today, the service itself is available in 21 transport regions and, for example, *VRB* considers to use the technology in the future.[438]

[436] See Haase (2009, pp. 256–261) and Wagner and Engelen (no date).
[437] See e.g. Wagner and Engelen (no date).
[438] See Regionalverband Großraum Braunschweig (2020, p. 427).

C Thresholds for market configurations

C.1 Uncovered market vs. just-covered market

Using prices from Equations (4.4) to (4.6) and the demand formulations in Table 4.4 for the just-covered and uncovered market give the following profit functions:

$$\begin{aligned}\Pi_1^{JCM}(s_1, s_2) &= D_1^{CM}(p_1^{JCM}, p_2^{JCM}) \cdot p_1^{JCM} \\ &= \frac{\theta_l s_1}{\Delta\theta}\left(\frac{\theta_u(s_2 - s_1) - \theta_l(2s_2 - s_1)}{2(s_2 - s_1)}\right)\end{aligned} \tag{C.1}$$

$$\begin{aligned}\Pi_1^{UM}(s_1, s_2) &= D_1^{UM}(p_1^{UM}, p_2^{UM}) \cdot p_1^{UM} \\ &= \frac{(\theta_u)^2}{\Delta\theta}\frac{s_1 s_2(s_2 - s_1)}{(4s_2 - s_1)^2}\end{aligned} \tag{C.2}$$

Next, the optimal choices for the respective s_1 values from Equations (4.7) and (4.8) can be substituted into these profit functions.

$$\begin{aligned}\Pi_1^{UM} =& \frac{(\theta_u)^2}{\Delta\theta}\frac{\frac{4}{7}s_2^2(s_2 - \frac{4}{7}s_2)}{(4s_2 - \frac{4}{7}s_2)^2} \\ \Pi_1^{JCM} =& \frac{\theta_l s_2\left(1 - \frac{\sqrt{\theta_l}}{\sqrt{\Delta\theta}}\right)}{\Delta\theta} \cdot \left(\frac{\theta_u\left(s_2 - s_2\left[1 - \frac{\sqrt{\theta_l}}{\sqrt{\Delta\theta}}\right]\right) - \theta_l\left[2s_2 - s_2\left(1 - \frac{\sqrt{\theta_l}}{\sqrt{\Delta\theta}}\right)\right]}{2\left[s_2 - s_2\left(1 - \frac{\sqrt{\theta_l}}{\sqrt{\Delta\theta}}\right)\right]}\right) \\ &= \frac{s_2\theta_l}{2\Delta\theta}\left(\theta_u - 2\sqrt{\theta_l}\sqrt{\Delta\theta}\right)\end{aligned}$$

Thus, setting these functions equal to each other gives:

$$\frac{1}{48}s_2(\theta_u)^2 = \frac{s_2\theta_l}{2}\left(\theta_u - 2\sqrt{\theta_l}\sqrt{\Delta\theta}\right)$$

Or even simpler:

$$\frac{1}{24}(\theta_u)^2 = \theta_l\left(\theta_u - 2\sqrt{\theta_l}\sqrt{\Delta\theta}\right) \tag{C.3}$$

Testing this relationship for $\frac{\theta_u}{\theta_l} = 10$ yields by substitution of $\theta_u = 10\theta_l$:

$$\begin{aligned}\frac{100}{48}(\theta_l)^2 &> \theta_l\left(10\theta_l - 6\theta_l\right)\\ \frac{25}{12} &> 2\end{aligned}$$

Meaning that the at the upper bound of the just covered market the equilibrium profit is higher playing the uncovered market solution. On the contrary, at the lower bound of the uncovered market playing the just covered quality level yields a higher profit. From $\frac{\theta_u}{\theta_l} = 8$ follows using Equation (C.3):

$$\begin{aligned}\frac{8}{3}(\theta_l)^2 &< \theta_l\left(8\theta_l - 2\theta_l\sqrt{7}\right)\\ \frac{8}{3} &< 2\left(4 - \sqrt{7}\right)\end{aligned}$$

Thus, within the interval $[8, 10]$ must be a point where firm 1 is indifferent playing either strategy. This point can be found by solving Equation (C.3) with $\theta_u = \xi\theta_l$. The result is the following polynomial:

$$\frac{1}{24}\xi^2 = \xi - 2\sqrt{\xi - 1}$$

Solving numerically, the unique solution within $[8, 10]$ is approximately 8.6581 and corresponds to the result in (4.10).

C.2 Just-covered market vs. covered market

The profit function for the just-covered market is given by Equation C.1 above. For the covered market, profit can be derived from the price function in Equation (4.2) and the corresponding demand formulation in Table 4.4. Explicitly, this yields:

$$\begin{aligned}\Pi_1^{CM}(s_1,s_2) &= D_1^{CM}(p_1^{CM},p_2^{CM})\cdot p_1^{CM}\\ &= \frac{\theta_l}{3\Delta\theta}\frac{(\theta_u-2\theta_l)^2}{\theta_u+\theta_l}\end{aligned} \tag{C.4}$$

At $\frac{\theta_u}{\theta_l}=5$ the two profit functions cross and, thus, the overall profit function in terms of the distribution parameters is continuous between these two market configurations. To show this, let $\theta_u = 5\theta_l$ and substitute this term into both profit functions:

$$\begin{aligned}\Pi^{JCM}_{1|\frac{\theta_u}{\theta_l}=5} &= \frac{s_2\theta_l}{2\cdot 4\theta_l}\left(5\theta_l - 2\sqrt{\theta_l}\sqrt{4\theta_l}\right)\\ &= \frac{s_2\theta_l}{8}\\ \Pi^{CM}_{1|\frac{\theta_u}{\theta_l}=5} &= \frac{s_2\theta_l}{3\cdot 4\theta_l}\frac{(3\theta_l)^2}{6\theta_l}\\ &= \frac{s_2\theta_l}{8}\end{aligned}$$

Therefore, profits for the low quality firm are equal at the transition from the covered market to the just-covered market. It still remains to show that with increasing heterogeneity (within the limits of an ex-ante covered-market, i.e. in the interval $(5,10]$) playing the just-covered solution yields higher profits for firm 1 than sticking to covered market solution. To show this, assume that $\frac{\theta_u}{\theta_l}=x$ and, as before, substitute θ_u in the profit functions (C.1) and (C.4). By taking the difference of the two functions, it remains to show that this difference exceeds zero within the relevant interval:

$$f(x) = \frac{s_2\theta_l}{2\theta_l(x-1)}\left(\theta_l x - 2\sqrt{\theta_l}\sqrt{\theta_l(x-1)}\right) - \frac{s_2\theta_l}{3\theta_l(x-1)}\frac{\left(\theta_l(x-2)\right)^2}{\theta_l(x+1)} \geq 0$$

After some simplifications this problem can be reduced to:

$$g(x) = x^2 + 11x - 8 - 6(x+1)\sqrt{x-1} \geq 0 \tag{C.5}$$

This function has two roots at $x = 2$ and $x = 5$. While the former is of no importance at this point, the latter is well known. However, the message of this analysis is that for $x > 5$ the function is monotone. This implies that the derivative of Equation (C.5) has to be of the same sign in the relevant range. The respective derivative condition is:

$$2x + 11 > \frac{3(3x-1)}{\sqrt{x-1}}$$

This inequality is satisfied for $x > 5$ as can easily be shown by numerically testing this equation.

Therefore, the preceding calculations show that for uniformly distributed quality valuations θ in a duopoly setting, the low quality firm will play the just-covered market solution within $5 \leq \frac{\theta_u}{\theta_l} \leq 8.6581$ and the uncovered-market solution beyond that last value. Indeed, the calculations in this section also prove that for $8.6581 \leq \frac{\theta_u}{\theta_l} \leq 10$ the covered solutions yields lower profits than the just-covered solution. The results form Appendix C.1 conclude the proof that playing the straight forward covered-market solution is superseded by both the just-covered and uncovered market solutions for $\frac{\theta_u}{\theta_l} \geq 5$ as they lead to higher profits for the low quality firm.

D Monopoly: primal feasibility

In this section, primary feasibility is validated for the four solution candidates that satisfy dual feasibility in the monopoly model in Chapter 6.1. The candidates are listed in 6.1 and for ease of use, the inequality constraints are listed again:

$$\begin{aligned} h_2(p_p) &= \frac{\kappa_\theta}{\Delta\theta}(s\theta_u - p_p) - s\kappa_\theta \leq 0 \\ h_3(p_p, p_t) &= p_t - \frac{\alpha_u \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_p}{s}\right) \leq 0 \\ h_4(p_p, p_t) &= \frac{\alpha_l \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{p_p}{s}\right) - p_t \leq 0 \end{aligned}$$

D.1 Solution candidate #1

For solution candidate #1 with

$$\begin{aligned} p_p &= \frac{4s\theta_u\Delta\alpha - \alpha_u^2\kappa_\alpha}{8\Delta\alpha} \\ p_t &= \frac{4s\alpha_u\theta_u\kappa_\theta\Delta\alpha + \alpha_u^3\kappa_\alpha\kappa_\theta}{16s\Delta\alpha\Delta\theta} \end{aligned}$$

primal feasibility of $h_2(p_p)$ gives:

$$\begin{aligned} \frac{1}{\Delta\theta}\left(s\theta_u - \frac{s\theta_u}{2} + \frac{\alpha_u^2\kappa_\alpha}{8\Delta\alpha}\right) - s &\leq 0 \\ \frac{\alpha_u^2\kappa_\alpha}{2\Delta\alpha(\theta_u - 2\theta_l)} &\leq s \end{aligned} \tag{D.1}$$

Thus, this condition delimits the parameter space and requires s to be greater than the left side of (D.1) for this restriction to be non-binding.

$h_3(p_p, p_t)$ gives:

$$\frac{4s\alpha_u\theta_u\kappa_\theta\Delta\alpha + \alpha_u^3\kappa_\alpha\kappa_\theta}{16s\Delta\alpha\Delta\theta} - \frac{\alpha_u\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s}\frac{4s\alpha_u\theta_u\kappa_\theta\Delta\alpha + \alpha_u^3\kappa_\alpha\kappa_\theta}{16s\Delta\alpha\Delta\theta}\right) \leq 0$$

This can be simplified to

$$-3\kappa_\theta - \frac{\alpha_u^2\kappa_\alpha}{4s\Delta\alpha} \leq 0,$$

which is satisfied as all parameters are positive.

For $h_4(p_p, p_t)$ follows:

$$\begin{aligned}\frac{\alpha_l\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s}\frac{4s\theta_u\Delta\alpha - \alpha_u^2\kappa_\alpha}{8\Delta\alpha}\right) - \frac{4s\alpha_u\theta_u\kappa_\theta\Delta\alpha + \alpha_u^3\kappa_\alpha\kappa_\theta}{16s\Delta\alpha\Delta\theta} &\leq 0 \\ 2 &\leq \frac{\alpha_u}{\alpha_l}\end{aligned}$$

This means, heterogeneity among transport providers must be such that the expected additional revenue created by platform participation is more than double for high valuing firms (α_u) in comparison to low valuing firms (α_l).

D.2 Solution candidate #2

The prices in case all transport firms join the platform are:

$$\begin{aligned}p_p &= \frac{s\theta_u - \alpha_l\kappa_\alpha}{2} \\ p_t &= \frac{\alpha_l\kappa_\theta(s\theta_u + \alpha_l\kappa_\alpha)}{2s\Delta\theta}\end{aligned}$$

With these, prices $h_2(p_p)$ can be written as:

$$\begin{aligned}\frac{1}{\Delta\theta}\left(s\theta_u - \frac{s\theta_u - \alpha_l\kappa_\alpha}{2}\right) - s &\leq 0 \\ \frac{\alpha_l\kappa_\alpha}{\theta_u - 2\theta_l} &\leq s \qquad \text{(D.2)}\end{aligned}$$

This inequality can be satisfied by several combinations. The simplest forms would be to reduce heterogeneity among passengers making the denominator less than zero. Alternatively, extensive heterogeneity of passengers (implying a large denominator) and low revenue potential potential of some transport firms (low α_l) combined with few transport firms (κ_α) make the left side of (D.2) small. Depending on the size of s, the inequality may hold.

The constraint, where no transport firms join the platform $h_3(p_p, p_t)$, can be simplified to:

$$\frac{\alpha_l \kappa_\theta (s\theta_u + \alpha_l \kappa_\alpha)}{2s\Delta\theta} - \frac{\alpha_u \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s}\frac{s\theta_u - \alpha_l\kappa_\alpha}{2}\right) \leq 0$$

$$\alpha_l - \alpha_u \leq 0$$

This condition is satisfied by definition.

For $h_4(p_p, p_t)$ follows the equality

$$\frac{\kappa_\theta \alpha_l}{\Delta\theta}\left(\theta_u - \frac{1}{s}\frac{s\theta_u - \alpha_l\kappa_\alpha}{2}\right) - \frac{\alpha_l \kappa_\theta (s\theta_u + \alpha_l \kappa_\alpha)}{2s\Delta\theta} = 0,$$

which is satisfied since the constraint is binding.

D.3 Solution candidate #3

When all passengers join and none of restrictions for transport firms is binding, prices are:

$$p_p = s\theta_l$$
$$p_t = \frac{\alpha_u \kappa_\theta}{2}$$

For constraint $h_2(p_p)$ equality is required as it is a binding constraint. After a few simple reformulations the equality of the constraint becomes apparent:

$$\frac{1}{\Delta\theta}\left(s\theta_u - s\theta_l\right) - s = 0$$

The non-binding constraint $h_3(p_p, p_t)$ is always satisfied, as:

$$\begin{aligned}\frac{\alpha_u \kappa_\theta}{2} - \frac{\kappa_\theta \alpha_u}{\Delta\theta}\left(\theta_u - \frac{1}{s} s\theta_l\right) &\leq 0\\ -\frac{\alpha_u \kappa_\theta}{2} &\leq 0\end{aligned}$$

To comply with the restriction that at most κ_α transport firms join, these firms are required to exhibit large enough heterogeneity among each other:

$$\begin{aligned}\frac{\alpha_l \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s} s\theta_l\right) - \frac{\alpha_u \kappa_\theta}{2} &\leq 0\\ 2 &\leq \frac{\alpha_u}{\alpha_l}\end{aligned}$$

D.4 Solution candidate #4

This extreme case, where both all passengers and all transport firms are affiliated with the intermediary, leads to the following prices:

$$\begin{aligned}p_p &= s\theta_l\\ p_t &= \alpha_l \kappa_\theta\end{aligned}$$

Plugging these prices into the restrictions $h_1(p_p)$, $h_2(p_p, p_t)$ and $h_4(p_p, p_t)$ gives:

$$h_2(p_p) = \frac{\kappa_\theta}{\Delta\theta}\left(s\theta_u - s\theta_l\right) - s\kappa_\theta = 0 \tag{D.3}$$

$$h_3(p_p, p_t) = \alpha_l \kappa_\theta - \frac{\alpha_u \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s} s\theta_l\right) \leq 0 \tag{D.4}$$

$$h_4(p_p, p_t) = \frac{\alpha_l \kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{1}{s} s\theta_l\right) - \alpha_l \kappa_\theta = 0 \tag{D.5}$$

While for Equations (D.3) and (D.5) the equality has to hold as the constraints are binding (which it does, as a few simplifications will show), the condition in Equation (D.4) yields $\alpha_l - \alpha_u \leq 0$, which is guaranteed by definition. Thus, this case does not impose further restrictions on the parameter space.

E Monopoly: solving the cubic equation

This appendix elaborates on the solution of the cubic equation encountered in the second stage in the monopoly setting in Chapter 6.1. Specifically, this appendix discusses the solution to the FOC in Equation (6.17) where the reduced profit function has been maximised with regards to the quality parameter s for the case where none of the demand constraints (from the first stage) is binding.

This FOC can be restated as:

$$\frac{\Delta\alpha\theta_u(4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha)\kappa_\theta}{8s(\Delta\alpha)^2\Delta\theta} - \frac{(4s\Delta\alpha\theta_u + \alpha_u^2\kappa_\alpha)^2\kappa_\theta}{64s^2(\Delta\alpha)^2\Delta\theta} - 2\eta s \overset{!}{=} 0$$

Simplifying the equation and collecting terms yields:

$$128(\Delta\alpha)^2\Delta\theta\eta s^3 - 16(\Delta\alpha)^2\theta_u^2\kappa_\theta s^2 + \alpha_u^4\kappa_\alpha^2\kappa_\theta = 0$$

To solve this system the approach by the Renaissance mathematicians del Ferro, Tartaglia and its generalisation by Cardan is followed. To keep matters simple, the numerical values in this equation are substituted by A, B and D:

$$As^3 - Bs^2 + D = 0 \tag{E.1}$$

The three solutions to Equation (E.1) are:

$$\begin{aligned}
s_1 =& \frac{1}{3}\left(\frac{B}{A} + \frac{2^{\frac{1}{3}}B^2}{A(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}}\right. \\
&\left. + \frac{(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}}{2^{\frac{1}{3}}A}\right) \qquad \text{(E.2)}\\
s_2 =& \frac{B}{3A} - \frac{(1 - i\sqrt{3})B^2}{32^{\frac{2}{3}}A(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}} \\
&- \frac{(1 + i\sqrt{3})(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}}{62^{\frac{1}{3}}A} \qquad \text{(E.3)}\\
s_3 =& \frac{B}{3A} - \frac{(1 + i\sqrt{3})B^2}{32^{\frac{2}{3}}A(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}} \\
&- \frac{(1 - i\sqrt{3})(2B^3 - 27A^2D + 3\sqrt{3}\sqrt{-4A^2B^3D + 27A^4D^2})^{\frac{1}{3}}}{62^{\frac{1}{3}}A} \qquad \text{(E.4)}
\end{aligned}$$

Solutions (E.3) and (E.4) are complex conjugates. These solutions are valid independent of the parameters used in the problem. However, the so called *casus irreducibilis* where $\Delta_3 > 0$ explicitly has three real roots.[439] Once the problem is constrained such that the discriminant is positive, there are two ways to describe these solutions as reals. The first is the trigonometric approach by Viète that is elaborated below and a second approach involves the hypergeometric function of Gauss.

Following Zucker (2008) on the trigonometric approach, Equation (E.1) is reformulated to:

$$s^3 - \frac{B}{A}s^2 + \frac{D}{A} = 0$$

Reducing this to the standard form by substituting $s = t + \frac{1}{3}\frac{B}{A}$ gives:

$$t^3 + 3pt + 2q = 0 \qquad \text{(E.5)}$$

[439] Cf. Equation (6.18).

with:

$$p = -\frac{1}{9}\left(-\frac{B}{A}\right)^2$$
$$q = \frac{1}{27}\left(-\frac{B}{A}\right)^3 + \frac{1}{2}\frac{D}{A}$$

The real roots of Equation (E.5) are then given by:

$$t_{1,2,3}^{trig} = 2\sqrt{-p}\cos\left(\frac{\arccos\left(\frac{-q}{\sqrt{-p^3}}\right) + 2k\pi}{3}\right) \qquad \text{with } k = 0, 1, 2$$

Reversing the transformation yields the corresponding real results for s. Note, however, the ordering of the results in Cardan's general solution do not match the ordering of Viète's real solution. I.e. in Equations (E.2)-(E.4) $s_1 < s_2 < s_3$ given a parameter space complying with $\Delta_3 > 0$, while $t_2^{trig} < t_3^{trig} < t_1^{trig}$ in the trigonometric approach.[440] The relations in the latter case are maintained during the reverse transformation:

$$s_2^{trig}(k = 1) < s_3^{trig}(k = 2) < s_1^{trig}(k = 0)$$

In consequence, the following solutions are the same:

$$s_1 \equiv s_2^{trig}(k = 1)$$
$$s_2 \equiv s_3^{trig}(k = 2)$$
$$s_3 \equiv s_1^{trig}(k = 0)$$

For the case where $\Delta_3 = 0$ there exists a multiple root. This means that at least two roots are associated with the same value. In the context of a monopoly platform such a multiple root corresponds to a saddle point where the positive local

[440]For the trigonometric approach the condition $\Delta_3 > 0$ holds by definition.

minimum and maximum vanish. For an equation in the form of (E.1) there exists a double root. This root is given by:

$$s_{1/2} = \frac{9AD}{2B^2} \tag{E.6}$$

For the uncovered monopoly profit $\Pi_{\#1}(s)$ in Equation (6.12) this root reads:

$$s_{1/2} = \frac{9}{4}\frac{\left(\frac{\kappa_\alpha}{\Delta\alpha}\right)^2}{\frac{\kappa_\theta}{\Delta\theta}}\left(\frac{\alpha_u}{\theta_u}\right)^4 \eta \tag{E.7}$$

By the definition of $\Delta_3 = 0$, Equation (6.19) holds with equality. Solving this equation for the cost parameter η yields:

$$\eta = \frac{\frac{\kappa_\theta}{\Delta\theta}}{\frac{\kappa_\alpha}{\Delta\alpha}}\frac{\theta_u^3}{27\alpha_u^2}$$

Subsituting this into the root in (E.7) gives:

$$s_{1/2} = \frac{1}{12}\frac{\kappa_\alpha}{\Delta\alpha}\alpha_u^2\theta_u^2$$

Comparing this value to the constraint $h_1(s)$ in (6.16) leads to the conclusion that only for $\Delta_3 > 0$ an interior solution can be obtained as the constraint is always to the right of the double root.

Similar agruments lead to slightly different results for case #2 where all transport firms are affiliated to the platform. Multiplying the FOC by $4s^2\Delta\theta$ leads to:

$$8s^3\Delta\theta\eta - s^2\theta_u^2\kappa_\theta + \alpha_l^2\kappa_\alpha^2\kappa_\theta = 0$$

The discriminant of this transformed FOC is:

$$\Delta_3 = 4\alpha_l^2\kappa_\alpha^2\kappa_\theta^2(\theta_u^6\kappa_\theta^2 - 432\alpha_l^2(\Delta\theta)^2\kappa_\alpha^2\eta^2)$$

Due to the transformation, the discriminant is slightly different to the one obtained in Chapter 6.1 in Equation (6.22). For the number of solutions to the cube, only

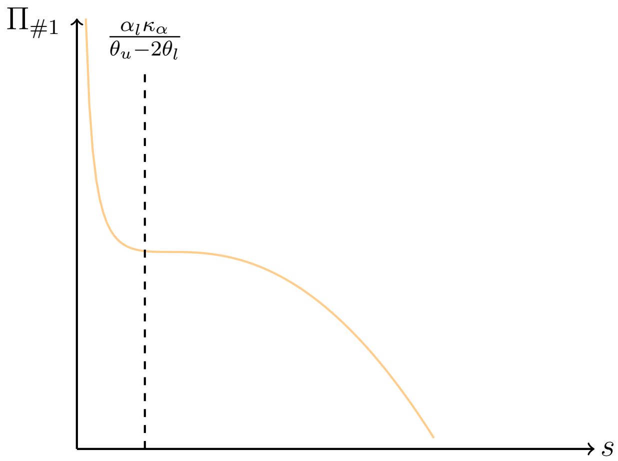


Figure E.1: Monopoly profit in case of a double root and low θ_l

the discriminant's sign matters and the terms in parentheses are, of course, the same.

For a zero discriminant in terms of η the following relation has to hold:

$$\eta = \frac{\theta_u^3 \kappa_\theta}{\sqrt{432}\alpha_l \Delta\theta \kappa_\alpha}$$

Together with Equation (E.6) the double root for case #2 is given by:

$$s_{1/2} = \sqrt{3}\frac{\alpha_l \kappa_\alpha}{\theta_u}$$

Taking the comparison with the constraint $h_1(s)$ in Equation (6.20) yields the result that only for $\sqrt{3}(\theta_u - 2\theta_l) < \theta_u$ the constraint is to the right of the saddle point. Thus, for small values of θ_l the relation will not hold and the constraint will lie to the left of the saddle point. This situation is shown in Figure E.1. Consequently, it cannot be ruled out that the threshold lies to the left of a local minimum in the case of $\Delta_3 > 0$. In these cases the platform needs to evaluate the profits for both the local maximum and value at the constraint in order to decide on optimal quality s.

F Duopoly: reduced transport prices

In Chapter 6.2.2 the duopoly setting has been analysed. The first stage included the decisions platforms make on the transport market side. Three possible market outcomes have been identified. These are an uncovered, just-covered and a covered transport market. For each configuration optimal prices have been derived and the scope of the respective cases has been defined. To keep matters simple and account for different market configurations in the passenger market, the network externality passengers exercise on transport firms has entered the equations by the demands $D_{p,1}$ and $D_{p,2}$ for the low quality and high quality platform, respectively.

For the second step, where intermediaries set prices on the other market side, it becomes necessary to define overall platform profits in terms of passenger price. Therefore, the demand terms in the optimal transport prices $p_{t,1}$ and $p_{t,2}$ are replaced by either the uncovered or covered demand definition of the passenger market defined in Table 6.4.

Equations (F.1) to (F.6) show these prices given an uncovered passenger market:

$$p_{t,1}^{UM} = \frac{\kappa_\theta}{\Delta\theta}\alpha_u \frac{\left(\frac{s_1 p_{p,2} - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)\left(\theta_u - \frac{s_1(2p_{p,2} - p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)}{4\theta_u - \frac{s_1(5p_{p,2} - 4p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}} \tag{F.1}$$

$$p_{t,2}^{UM} = \frac{2\kappa_\theta}{\Delta\theta}\alpha_u \frac{\left(\theta_u - \frac{p_{p,2} - p_{p,1}}{s_2 - s_1}\right)\left(\theta_u - \frac{s_1(2p_{p,2} - p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)}{4\theta_u - \frac{s_1(5p_{p,2} - 4p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}} \tag{F.2}$$

$$p_{t,1}^{JCM} = \frac{\kappa_\theta}{\Delta\theta}\alpha_l \left(\frac{s_1 p_{p,2} - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right) \tag{F.3}$$

$$p_{t,2}^{JCM} = \frac{\kappa_\theta}{2\Delta\theta}\left(\alpha_u\left(\theta_u - \frac{s_1(2p_{p,2} - p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right) - \alpha_l\left(\frac{s_1 p_{p,2} - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)\right) \tag{F.4}$$

$$p_{t,1}^{CM} = \frac{1}{3}\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{s_1(2p_{p,2} - p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)(\alpha_u - 2\alpha_l) \tag{F.5}$$

$$p_{t,2}^{CM} = \frac{1}{3}\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - \frac{s_1(2p_{p,2} - p_{p,1}) - s_2 p_{p,1}}{s_1(s_2 - s_1)}\right)(2\alpha_u - \alpha_l) \tag{F.6}$$

For the covered passenger market the results are:

$$p_{t,1}^{UM} = \frac{\kappa_\theta}{\Delta\theta}\alpha_u \frac{\left(\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} - \theta_l\right)\left(\theta_u - 2\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l\right)}{4\theta_u - 5\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l} \tag{F.7}$$

$$p_{t,2}^{UM} = \frac{2\kappa_\theta}{\Delta\theta}\alpha_u \frac{\left(\theta_u - \frac{p_{p,2} - p_{p,1}}{s_2 - s_1}\right)\left(\theta_u - 2\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l\right)}{4\theta_u - 5\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l} \tag{F.8}$$

$$p_{t,1}^{JCM} = \frac{\kappa_\theta}{\Delta\theta}\alpha_l\left(\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} - \theta_l\right) \tag{F.9}$$

$$p_{t,2}^{JCM} = \frac{\kappa_\theta}{2\Delta\theta}\left(\alpha_u\left(\theta_u - 2\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l\right) + \alpha_l\left(\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} - \theta_l\right)\right) \tag{F.10}$$

$$p_{t,1}^{CM} = \frac{1}{3}\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - 2\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l\right)(\alpha_u - 2\alpha_l) \tag{F.11}$$

$$p_{t,2}^{CM} = \frac{1}{3}\frac{\kappa_\theta}{\Delta\theta}\left(\theta_u - 2\frac{p_{p,2} - p_{p,1}}{s_2 - s_1} + \theta_l\right)(2\alpha_u - \alpha_l) \tag{F.12}$$

Similar to the expressions in the revenue Equations (6.42) to (6.47) the solutions for the covered transport market (Equations (F.5), (F.6), (F.11) and (F.12)) contain no multiplicative terms.

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