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**Audit market segmentation - The impact of
mid-tier audit firms on competition -**

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–The impact of mid-tier audit firms on competition–

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Abstract

It is a global phenomenon that more than 75% of a developed country's listed companies are clients of a Big-4 auditor. However, the economic consequences of this concentration are inconclusive. On the one hand, a kind of 'similarity'-hypothesis suggests that the existence of a few global auditors might induce Bertrand-oligopoly-like national audit market structures due to a lack of auditor differentiation in size and quality. Consequently, virtually no profits should be gained by the audit companies. On the other hand, the 'too-big-to-fail'-hypothesis suggests that governmental bodies might refrain from sanctions against Big-4 auditors, because they are afraid of further consolidating an oligopolistic market structure by dissolving another major supplier. In the long run, impairing competition could result in rather high audit profits.

Irrespective of which hypothesis they adhere to, regulating authorities recently recognized enabling mid-tier auditors to serve large multinational clients as a promising cure for the aforementioned problems. Accordingly, the goal of our paper is to develop a comprehensive model of audit market segmentation for analyzing the competitive impact of mid-tier auditors. As a modeling device we make use of a Hotelling setting, which has several advantages: Firstly, it depicts strategically motivated product differentiation, i.e., auditors supplying different quality levels can be analyzed. Secondly, in contrast to perfect competition models, in our model most audit firms realize non-negative profits better describing business practice. Thirdly, explicitly matching suppliers and customers allows to distinguish supply-side and demand-side audit quality.

Major results of our analysis are the following: A loss in high-quality auditors' flexibility to customize their audit programs is followed by an increase of audit quality offered by mid-tier firms. But, if mid-tier firms left the audit market, the Big-4 firms would raise the offered quality level, incurring growing profits as well. Further, the "market power" hypothesis stating that greater market shares imply rising fees can be supported theoretically.

Key Words: Auditor Concentration, Audit Market Structure, Big-4, Hotelling, Mid-tier Auditors, Product Differentiation, Segmentation

JEL classification: M42, D43

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1 Introduction

In the last decade, the Big-4 auditors have increased their market shares, hence, nowadays in most developed countries more than 75% of the listed companies are clients of a Big-4 auditor.[1] As a consequence of *Arthur Andersen's* demise the Hirschmann-Herfindahl Index exceeded by 40% the anti-competitive warning level as defined by the US Department of Justice.[2] The reason for this audit supplier concentration is that "[m]id-tier [audit] firms have significant difficulty competing for large, multinational companies as clients, and face legitimate and artificial barriers to acquiring a larger share of the audit market."[3] From the mid-tier auditors' point of view, major obstacles are caused by capacity and other size-related restrictions.[4] Moreover, clients consider auditor reputation to be an important factor influencing their access to capital markets and they attribute the highest reputation to Big-4 auditors.[5] As a result, reputational concerns cause another market-entry barrier for mid-tier auditors. Consequently, most national audit markets form 'tight oligopolies'.[6] This could comprise the risk of collusive behaviour including coordination of price setting and reduction of supplied audit quality. Contradicting these concerns, a kind of 'similarity'-hypothesis suggests that the existence of a few global auditors might induce Bertrand-oligopoly-like national audit market structures. This can be explained by a lack of auditor differentiation in size and quality. Consequently, virtually no profits should be gained by the audit companies.[7] Irrespective of which view holds true, a severe drawback of the present audit market structure became obvious, when "the [US-]government in 2005 chose not to indict KPMG despite its admitted federal crimes in peddling numerous illegal tax shelter schemes."[8] This event may serve as an anecdotal evidence for the 'too-big-to-fail'-hypothesis, describing governmental bodies' dilemma: On the one hand, refraining from sanctions might induce a reduction in audit quality, because taking no actions signals the litigation risk can be perceived as non-existent. On the other hand, taking measures could result in dissolving a Big-4 auditor, further consolidating the audit market's oligopolistic structure. Such an intervention is potentially accompanied by audit quality reduction due to relaxed competition. Additionally, audit profits might increase in the long run.

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[1]Table 1 exhibits a literature review of studies on country-specific concentration levels, see page 5.

[2]Cf. *Cox* (2006, p. 272).

[3]Cf. *The American Assembly* (2005, pp. 6).

[4]Cf. *Oxera Consulting Limited* (2006, p. 59): "[M]ost mid-tier firms ... would not be particularly keen to audit just one of the largest public companies ..., since such an audit would absorb a large proportion of their resources."

[5]Cf. *Ewert/London Economics* (2006, p. xxviii): "These barriers [mid-tier firms face] are unlikely to be overcome in the very near-term as the build-up of reputation, ... take[s] time and resources."

[6]Concentration ratios exceeding 60% are regarded as 'tight oligopolies', cf. *Beattie/Fearnley* (1994, p. 308).

[7]Cf. *Tonge/Wootton* (1991, p. 170).

[8]Cf. *Cunningham* (2006, p. 1699).

Considering these facts, regulating authorities recently recognized enabling mid-tier auditors to serve large multinational clients as a promising cure for the aforementioned problems. Increasing the number of competitors in a given audit market segment would offer the clients a greater freedom of choice. Furthermore, this would provide a "credible alternative to the prevailing auditing industry structure so that a firm facing failure can be allowed to exit without disrupting the financial system that audit firms support."[9] Eventually, some mid-tier auditors engaged in merger talks, adopting the idea to narrow the gap between high and middle quality segments.[10] For example, in Canada, the national offices of *Grant Thornton* and *BDO* discussed a merger "... to become more competitive with the top 4 firms."[11] In the UK, *Grant Thornton* successfully merged with *Robson Rhodes*, becoming the fifth biggest audit company in the UK now being of comparable size to *BDO Stoy Hayward*.[12] But it remains doubtful whether mergers and acquisitions are an appropriate means to overcome the existing gap.[13]

This emphasizes that auditors' differentiation strategy is – in contrast to industry specialization – not well understood, yet. Although a lot of empirical based studies on Big-4 versus non-Big-4 auditors exist, a theory of audit segmentation is still lacking. Accordingly, the goal of our paper is to develop a comprehensive model of audit market segmentation. The analysis focuses on the strategic positioning of mid-tier audit firms emphasizing how they influence competition and the average supply-side quality in the audit market. As a modeling device we make use of a Hotelling setting, which has several advantages: Firstly, it depicts strategically motivated product differentiation, i.e., auditors supplying different quality levels can be analyzed. Secondly, in contrast to perfect competition models, in our model most audit firms realize non-negative profits better describing business practice. Thirdly, explicitly matching suppliers and customers allows to distinguish a supply-side and demand-side audit quality. Moreover, we are able to analyze the emerging consequences if mid-tier auditors resigned from offering audit services.

Major results of our analysis are the following: A loss in the flexibility of high quality auditors to customize the audit program is followed by an increase of the audit quality of mid-tier firms. But, if mid-tier firms left the audit market, the Big-4 firms would raise the offered quality level, incurring growing profits as well. The paper contributes to the literature by explaining quality differentiation of auditing. We scrutinize how audit market segmentation arises in response to competition demonstrating that offered supply-side qualities align with client requirements, i.e., a matching between supply perspective

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[9] *Cunningham* (2006, p. 1699).

[10] According to *Duxbury/Moizer/Wan-Mohamed* (2007) an audit firm merger enhances the attractiveness of non-top tier firms.

[11] Cf. *Reuters* (2007). However, the negotiation finally failed.

[12] Cf. *Jetuah* (2007).

[13] Cf. *Ewert/London Economics* (2006, p. xxx).

and demand perspective in auditing results. The remainder of the paper is organized as follows: In section 2 a literature review covering audit competition and audit quality is given. In section 3 the economic setting and the model assumptions are described. Section 4 summarizes the main results.

2 Literature Review

Auditors serve as "gatekeepers of the public securities markets."[14] Accordingly, standard-setting bodies in the US and the EU dedicate a lot of effort to guarantee valuable audits,[15] because they fear what *Cox* (2006) calls an 'oligopolistic gatekeeper'.[16] This literature review covers both – a macroperspective and a microperspective – explaining the supply-side of the audit market. The macroperspective focuses on the ongoing concentration processes. The microperspective is dedicated to the tendencies of specialization and segmentation. Further, the demand perspective specifying certain audit quality requirements is considered as well. The different perspectives addressed in the literature review are summarized in Figure 1.
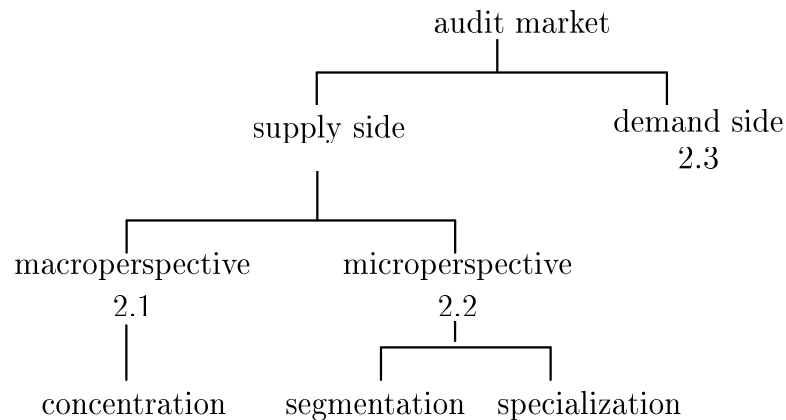
Fig. 1: Perspectives of the audit market

2.1 Macroperspective – The ongoing concentration process

In the 1980s and 1990s several empirical studies found evidence supporting the hypothesis of competitive audit markets.[17] At that time the market structure was characterized by the so-called Big-8. However, the mergers of *Arthur Young* with *Ernst & Whinney* and of *Deloitte, Haskins & Sells* with *Touche Ross* in 1989 reduced the Big-8 to the Big-6. In

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[14]Cf. *Ghosh/Moon* (2005, p. 588).
[15]Cf. *Willekens/Simunic* (2007, p. 217).
[16]Cf. *Cox* (2006, p. 269).
[17]Cf. *Maher* et al. (1992, p. 206), *Palmrose* (1986, p. 108), *Francis* (1984, p. 147), *Simunic* (1980, p. 187).

1998, *Pricewaterhouse* and *Coopers & Lybrand* combined to *PwC* creating the Big-5, and in 2001 *Arthur Andersen* collapsed leaving the Big-4.[18]

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[18]Cf. *Pong/Burnett* (2006), *GAO* (2003, p. 11), *Iyer/Iyer* (1996).

	country	market share	year (survey)	concentration measure	
Zijl/Karim (2008)	BAN	32.9%	2003	AF	CR_4
Weets/Jegers (1997)	BEL	61.0%	1994	TA	CR_4
Willekens/Achmadi (2003)	BEL	46.5%	2003	No. of Clients	CR_6
DeFond/Wong/Li (2000)	CHN	52.0%	1996	TA	CR_4
Christiansen/Loft (1992)	DEN	71.0%	1990	REV	CR_4
Piot/Janin (2007)	FRA	56.7%	2003	weighted MS	CR_4
Piot (2001)	FRA	55.8%	1997	No. of Clients	CR_6
Albach (1976)	GER	79.5%	1971	TA	CR_5
Ashbaugh/Warfield (2003)	GER	72.3%	1997	Client Sales	CR_2
Lenz/Ostrowski (1999)	GER	94.3%	1996	TA	CR_6
Marten/Schultze (1998)	GER	76.9%	1994	REV	CR_4
DeFond/Francis/Wong (2000)	HKG	75.4%	1992	AF	CR_3
Lee (1996)	HKG	88.4%	1990	AF	CR_6
Baskerville/Hay (2006)	NZL	88.5%	1994	AF	CR_4
Stefani (2006)	SUI	98.9%	2002	AF	CR_4
Beattie/Goodacre/Fearnley (2003)	UK	97.8%	2002	AF	CR_4
McMeeking (2007)	UK	85.0%	2002	No. of Clients	CR_4
Oxera Consulting Limited (2006)	UK	99.0%	2004	AF	CR_4
Pong/Burnett (2006)	UK	95.2%	2001	AF	CR_5
Pong (1999)	UK	79.4%	1995	AF	CR_4
Thavpalan/Moroney/Simnett (2002)	UK	79.1%	1998	AF	CR_4
Danos/Eichenseher (1986)	USA	88.6%	1980	REV	CR_8
Doogar/Easley (1998)	USA	85.1%	1995	TA	CR_6
Tonge/Wootton (1991)	USA	62.6%	1989	REV	CR_4
Buijink/Maijoor/Meuwissen (1998)	GER, NED	16.0%, 52.0%	1994	Auditors/Audit Firm	CR_4
Choi/Zeghal (1999)	F, SWE, USA	43.9%, 76.5%, 67.0%	1991	AF	CR_4
Narasimhan/Chung (1998)	CAN, UK	75.8%, 92.9%,	1994	TA	CR_4
	HKG, SIN	88.9%, 93.6%	1994	TA	CR_4
Fan/Wong (2005)	ASIAN	60.6% − 91.9%	1996	No. of Clients	CR_5

Tab. 1: Studies of Market Concentration

AF = Audit Fees, TA = Total Assets, REV = Revenues, MS = Market Share, CR_i = concentration ratio with $i = 3, 4, 5, 6, 8$ denoting the number audit firms.

Consequently, e.g., *DeFond/Franics/Wong* (2000), *Buijink/Maijoor/Meuwissen* (1998), or *Pearson/Trompeter* (1994) diagnose a prevailing tendency of concentration in audit markets. Table 1 confirms this evidence by surveying concentation studies focussing on the Anglo-Saxon, the Continental-European and the Asian audit markets. It considers concentration ratios and itemizes the assessment basis, the year of the survey and the concentration index. The results show that in most developed countries, the concentration ratio for the four biggest firms exceeds the 75%-level. Only in France and Belgium lower levels of concentration are observed.[19] Unfortunately, differing measures, e.g. audit fee, total assets etc., for determining the concentration ratios allow only limited comparison of the studies. Besides, using total assets, revenues or number of clients usually distorts the concentration level. However, the dominant market position of the Big-4 firms is obvious.

In a recent study, *Ewert/London Economics* (2006) focussed on fees instead of the number of audit mandates to calculate concentration ratios for companies listed on regulated national stock exchanges. The results are in accordance with the ones discussed above as can be inferred from Table 2. Here, the concentration ratios (in %) of all EU-audit markets are depicted as of end of 2004.[20]

	AUT[21]	BEL	CYP	DEN	ESP	EST	FIN	FRA	GER	GRE	HUN	IRL
C1	43	48	30	30	78	34	74	28	57	31	60	41
C2	78	69	59	45	92	61	94	45	82	51	80	81
C4	93	96	90	77	99	94	100	71	92	73	99	99
C8	96	97	95	98	100	–	–	90	96	97	99	100
ITA	LAT	LIT	LUX	MLT	NED	POL	POR	SLO	SVK	SWE	TCH	UK
34	30	68	46	63	29	56	64	49	95	37	56	36
62	53	77	79	99	57	69	81	89	98	67	76	59
100	81	93	96	100	100	83	93	100	100	99	94	100
–	93	100	–	–	–	94	99	100	–	100	99	–

Tab. 2: Concentration ratios for the audit markets of the EU member states

The corresponding 'market power'-hypothesis states that greater market shares imply rising fees, whereas the 'competition'-hypothesis predicts the opposite.[22] However, empirical evidence on both hypotheses is inconclusive, probably because a theoretical foundation of audit market segmentation is lacking. Although the intensity of competition cannot be inferred from concentration ratios only, the findings exhibit the importance of our model. Firstly, we are able to form expectations on fee changes as a consequence of changing market shares, supporting either the 'market power'-hypothesis or the 'competition'-hypothesis. Secondly, we can derive predictions on how audit qua-

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[19]The same holds true for Spain and Luxembourg, cf. *Broye/Weill* (2008, p. 723).
[20]Cf. *Ewert/London Economics* (2006, p. 22, Table 5). A recent survey by *Grant Thornton* (2007) yields similar results.
[21]Country abbreviations follow the standard of the International Olympic Committee.
[22]Cf. *Willekens/Achmadi* (2003, p. 443).

lity depends on market shares and market concentration. Thirdly, taking into account that in some EU-member states mid-tier auditors are virtually extinct, our model results could serve as a starting point of empirical research on European audit markets and the prevalent overall audit quality.

2.2 Microperspective – Specialization and Segmentation

In the previous section factors influencing the market structure being beyond the individual auditor's control have been discussed. In this section the auditors' strategic actions, industry specialization and market segmentation,[23] are considered. Specialization means that auditors concentrate on certain industries reaping benefits from economies of scope and economies of scale. In contrast, segmentation implies that different auditors offer different levels of quality.[24] Note that the type of audit strategy adopted by an audit firm provides a competitive advantage in certain audit market segments, for supporting evidence see *Francis* (2004, p. 354), *DeFond/Franics/Wong* (2000, p. 49), or *Hogan/Jeter* (1999, p. 15). Figure 2 illustrates the notions of segmentation and specialization:
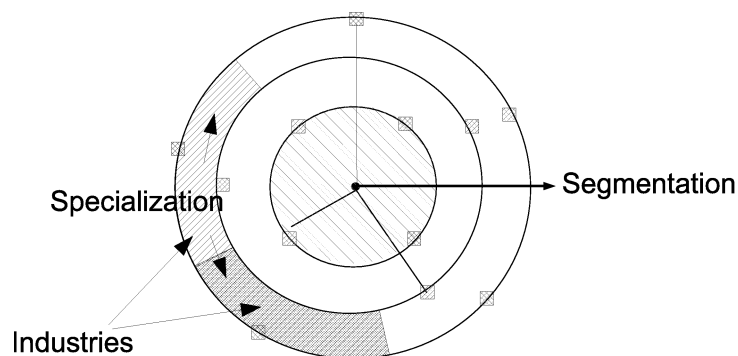

Fig. 2: Segmentation and specialization

Let the circular area represent all clients. Following the radius from the center to the boundary of the circle means that the audit quality demanded by the respective client decreases. Hence, quality segmentation is represented by moving along the radius. In contrast, industry specialization is represented by moving along the circumference. Here, a certain sector depicts a respective industry. In reality, both strategic options interfere, because, "[d]ifferential demand for auditing allows multiple types of audit quality to co-exist in the same industry and leads to ... product differentiation ..."[25]

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[23] For a further explanation of terminology, cf. *Beattie/Goodacre/Fearnley* (2003, p. 254) or *Kaplan/Krishnagopal/Williams* (1990).

[24] Cf. *Feltham/Hughes/Simunic* (1991, p. 377): "[L]iterature on audit quality, ... has ... demonstrated the existence of two or perhaps three distinct auditor quality levels."

[25] *Craswell/Francis/Wong* (1995, p. 300).

Obviously, auditors benefit from industry specialization,[26] because becoming an expert allows to increase fees and generates cost advantages,[27] as serving a group of clients with similar characteristics yields fixed costs degression.[28] As a matter of fact, for some clients' industries the US audit market forms a virtual monopoly or duopoly.[29] In contrast, segmentation's advantages are less obvious. Irrespective of the considered country, national audit markets are typically divided into three segments closely related to the audit firms' size or reputation, namely Big-4 auditors, national majors and regional/local auditors. In our model, we use audit quality as criterion of segmentation instead of size or reputation. This is done for three reasons. Firstly, quality-differentiation depends on the specification of the audit program and thus reflects the supply-side of auditing.[30] Secondly, empirical findings give rise to the assumption that large and brand-named audit firms are regarded as high quality suppliers of audits.[31] Thirdly, higher audit quality –probably conveyed by reputational effects– would rationalize the existence of Big-X fee premia.[32] Several empirical studies report such Big-X premia between 20 % and 30 %.[33] Interpreting the observed fee premia for Big-X auditors as a quality indicator seems plausible due to the findings that Big-X auditors are more restrictive on vague accounting practices and impede earnings management.[34] Therefore, Big-X auditors attract a higher credibility on the part of capital market participants, as usually shown in higher earnings response coefficients.[35]

Besides strategic motivations of the audit firms the impact of regulatory changes

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[26]Cf., e.g., *Mayhew/ Wilkins* (2003, p. 34): "[A]n audit firm obtains a significantly higher market share than its competitors – thereby differentiating itself – its bargaining power increases because clients cannot obtain similar quality services from competing audit firms. Under these circumstances, the audit firm may be able to earn a fee premium for its differentiated services."

[27]Cf. *Ferguson/ Francis/ Stokes* (2003).

[28]Cf. *Cox* (2006, p. 271), *Dunn/ Mayhew* (2004, p. 37), *Neal/ Riley* (2004, p. 170), *Mayhew/ Wilkins* (2003, p. 33), *Hogan/ Jeter* (1999, p. 2).

[29]Cf. *Cox* (2006, p. 272). For instance, *PWC* audits 76.4% of total assets of the petroleum and coal industry, *KPMG* audits nearly 60% of the assets of non-depositary institutions and *E&Y* audits 60.7% of the total assets of the general building contractors industry.

[30]Cf. *Blokdijk* et al. (2006).

[31]Cf. *Niemi* (2004, pp. 543). Similarly, *Craswell/ Francis/ Wong* (1995, p. 298, Fn. 3) state: "[W]hat the brand name argument means is that some accounting firms voluntarily invest in higher levels of expertise beyond the minimum required by professional standards and therefore have incentives to maintain their reputations by producing higher-quality audits."

[32]Big-X represents either Big-8, Big-6, Big-5 or Big-4.

[33]Cf. *Basioudis/ Francis* (2007, p. 158) conclude that city leadership is a sufficient condition to realize a fee premium in the UK. *Huang* et al. (2007, p. 156) observe that an auditor's bargaining power increases premia gathered from small clients. *Taylor/ Simon* (1999, p. 384) find a large firm fee premium on a global level. Similarly, *Craswell/ Francis/ Wong* (1995, p. 310) report a premium of 34 % for the Australian audit market. *Francis/ Stokes* (1986, p. 392) find Big-8 premiums on the Australian market for small auditees, only. *Francis* (1984, p. 142) reports a premium for the Australian Big-8. *Rose* (1999, pp. 150) and *Simon* (1992, p. 239) considering the examples of Malaysia and Singapore show that Big-6 premiums are prevailing in markets for multinational clients.

[34]Cf. *Kim/ Chung/ Firth* (2003), *Becker* et al. (1998), *DeFond/ Jiambalvo* (1993), or *Palmrose* (1986, p. 107).

[35]Cf. *Teoh/ Wong* (1993, p. 354).

on segmentation has to be observed, too. In the post-SOA period, a number of local and regional audit firms left the market for SEC audit engagements. Reasons for resigning on part of the audit firms have been increasing audit costs, increasing liability insurance costs and time-consuming inspections of regulatory authorities.[36] Moreover, the number of mid-sized audit firms decreased in the past, so primarily only a few large and several small players remained.[37] Correspondingly, *Carson* et al. (2004) find that a large number of auditors compete for small clients whereas the market for large clients is covered only by a small number of auditors.

Overall, the microperspective has the following implications for our model. We abstract from industry specialization as it occurs in all segments and begin our analysis in accordance with *Feltham/Hughes/Simunic* (1991) by distinguishing three quality levels. We presuppose that auditors understand their quality decision as a strategic device of coping with competition. Further, we assume that auditor's cost considerations determine the segment to be served.

2.3 Demand-side for audit services

In line with prior studies, we distinguish between demands for certain audit quality levels and demands for certain price levels.[38] Assessing auditor differentiation and audit quality presupposes "that there are many different kinds of audit firms which suggest there is a supply of differential auditing demanded by different clienteles."[39] The demand for different audit quality levels is explained by agency conflicts and problems of incomplete contracting. Auditors play a crucial role in modern international corporate governance, as they mitigate agency-conflicts among management and shareholders, among different groups of shareholders, like majority and minority interests, and among equity and debt suppliers.[40] Furthermore, empirical evidence indicates that share dispersion is accompanied by agency concflicts, thus, in these cases a Big-X auditor is appointed more frequently. Besides, *Francis/Wilson* (1988, p. 680) show that the appointment of a high quality auditor coincides with lower costs of capital. Similar results apply for risk premia of loans or interests on debts.[41] Moreover, while large companies benefit from the auditor's international network and highly skilled staff,[42] they may also decide for prestigous auditors because of signalling effects.[43] However, the legal environment and the liability regime at

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[36] Cf. *Read/Rama/Raghunandan* (2004, p. 253).
[37] Cf. *Niemi* (2004, pp. 547).
[38] Cf. *Dunmore/Falk* (2001, p. 306), *Feltham/Hughes/Simunic* (1991).
[39] *Francis* (2004, p. 352).
[40] Cf. *Fan/Wong* (2005, pp. 37), *Mansi/Maxwell/Miller* (2004, pp. 756), *Ashbaugh/Warfield* (2003, p. 4), *Piot* (2001, p. 486).
[41] Cf. *Mansi/Maxwell/Miller* (2004), *Pittman/Fortin* (2004).
[42] Cf. *Broye/Weill* (2008, p. 716).
[43] Cf. *Titman/Trueman* (1986).

hand are important constraints of auditor quality choice.[44] Especially, in IPO settings informational asymmetries exist and might harm the equity values.[45] Therefore, the demand for auditing can either be explained by an information or an insurance hypothesis.

Demand for different prices becomes obvious when auditees similar in size or complexity occasionally prefer different types of auditors. Deciding for a 'high quality' auditor might be associated with signalling the client's characteristics, while auditees choosing a 'low quality' auditor focus primarily on cost-efficiency. Another possible explanation for clients' auditor choice, might be that clients try to reduce audit fees by auditor switching until cost savings do no longer exceed costs of switching.[46] *Knechel/Niemi/Sundgren* (2008, pp. 68) and *Gassen/Skaife* (2007) emphasize that the most important arguments for auditor choice depend on client characteristics, i.e. size and complexity. Small clients' auditor choice is driven by internal considerations, whereas mid-size companies focus on arguments regarding financing. Large clients' choice is influenced by listing attributes and considerations of the own competition environment.

The main implication from this section is that clients differ in their requirements for audit quality, hence, in our model clients are sorted according to their auditing needs. As a model result, a perfect matching of the clients' quality demands and the auditors' quality supplies arises.

2.4 Modelling product differentiation & market competitiveness

Economics provides two types of models coping with differentiation strategies in competitive environments:[47] Circular cities – as considered by *Vickrey* (1999), *Schmalensee* (1983), or *Salop* (1979) – and linear spatial competition, as considered in *Hotelling* (1929). With respect to cirular models irrespective of whether Bertrand- or Cournot-competition is prevalent, equi-distant positionings form an equilibrium.[48] Hence, this type of model allows describing audit market specialization without any assumptions referring to audit market competitiveness. However, linear spatial models provide important advantages for analyzing audit market segmentation. In contrast to circular models, positionings do not need to be equi-distant allowing to model differently severe competition. Particularly, position dependent costs can be included[49] representing in our setting the different fixed costs auditors incur for providing back-up offices and quality related add-ons. In an audit application of a linear spatial competition model, *Chan* (1999, p. 613) explains varying degrees of audit market's competitiveness by considering specializiation and price setting

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[44]Cf. *Broye/Weill* (2008, pp. 725).
[45]Cf. *Willenborg* (1999) and *Beatty* (1989).
[46]Cf. *Kallunki/Sahlström/Zerni* (2007, p. 166).
[47]Cf. *Tirole* (2003, pp. 277).
[48]Cf. *Kats* (1995).
[49]Cf. *Moorthy* (1988).

as auditor's decision variables. It turns out that consequences of competition can be partially offset by specialization. However, in contrast to our model, *Chan* (1999) focussing on low-balling and assumes auditing to be a homogenous good and, thus, cannot address segmentation.

3 The Model

The empirical evidence provided in Tables 1 and 2 highlights that high quality auditors typically serve listed companies. Accordingly, we assume that high quality firms audit clients with high-quality needs. Mid-tier auditors serve clients who are still concerned about audit quality, but cannot benefit from the infrastructure of a high quality auditor. Finally, low quality auditors conduct all remaining mandatory audits. Coping with such a quality differentiated market structure, we implement a modified Hotelling setting. Given competition on the one hand between low quality auditors and mid-tier firms and on the other hand between high quality auditors and mid-tier firms three quality segments have to be derived model-endogenously.

3.1 Assumptions

We assume clients to be uniformly distributed on a continuum of length 1. The position r, $r \in [0,1]$, indicates the client's preference over audit quality, i.e., clients are strictly ordered. The client demanding the lowest quality is located at position $r = 1$, whereas the client demanding the highest level of quality is located at $r = 0$. Due to mandatory auditing each client has to hire an auditor, thus, the demand for audit services is given exogenously.[50] However, the demanded audit quality depends on the according costs and benefits.[51] The client demanding the lowest quality level only fulfills the legal requirement to be audited at minimum price. In contrast, a client demanding high quality, intends to achieve an audit value-added, e.g., reducing information asymmetrie, alleviating agency conflicts as well as yielding insurance from a high quality auditor, see page 9. Therefore, the client's willingness to pay, $\omega(r)$, is negatively related to his position, i.e., $\omega(r) = 1 - r$. Introducing $\omega(r)$ defines an upper bound of attainable audit fees.[52] Note that the willingness to pay will not be exploited in a competitive environment, because the attainable fees are defined as the miminum of the willingness to pay and the costs arising from appointing the second cheapest auditor, see Figure 3.

Given three quality levels, the auditor's position is i_j, $j \in \{1, 2, 3\}$, on the intervall

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[50]For a similar assumption cf. *Dunmore/Falk* (2001, p. 305).

[51]Cf. *Blokdijk* et al. (2006, p. 28) and section 2.3.

[52]Cf. *Eaton* (1972), *Smithies* (1941), and *Lerner/Singer* (1937) for a similar idea of introducing inverse demand functions into Hotelling settings.

[0, 1], with j refering to the quality level, differentiating for high ($j = 1$), middle ($j = 2$) and low ($j = 3$). Concentrating on mandatory audits, the low quality firm has to provide services for the least demanding client. Thus, to achieve market clearing $i_3 = 1$ is assumed as exhibited in figure 3.[53] Auditors' position choice defines their supply-side quality. The quality level results from the implemented technology, but is irrespective of the individiual client's needs. The gap between supply-side quality and the client's quality demand contributes to the audit costs. Hence, we assume the cost function to be

$$C_{i_j}(r) = \frac{1}{i_j}|i_j - r|\theta_j; \quad \text{with } j \in \{1, 2, 3\}, i \in [0, 1] \tag{1}$$

Total audit costs, C_{i_j}, account for a client located at position r and are influenced by the quality-related flexibility parameter θ_j.
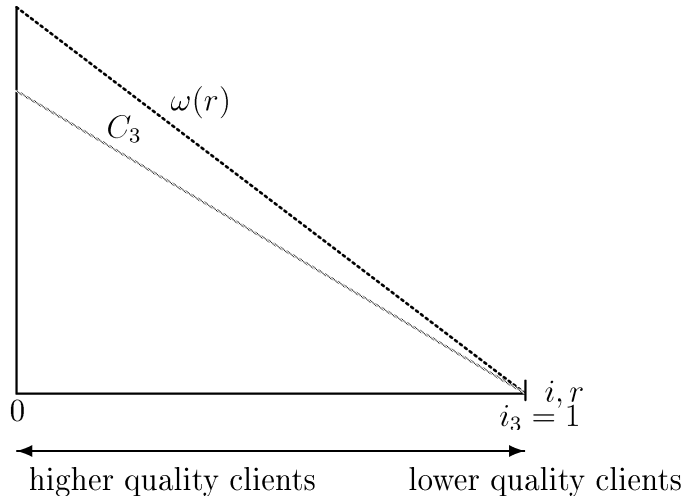

Fig. 3: Willingness to pay and position of low quality auditor

Firstly, refering to the auditor's quality level decision, the cost component $\frac{1}{i_j}$ captures the effect of supply side quality and can for example be interpreted as costs per hour. Of course, highly skilled and educated auditors' hourly wage rates are higher than those of less experienced auditors. Secondly, as a consequence of the chosen supply side quality, i_j, adjustments of the audit methodology result. To fit the clients' individual profiles and to be conform with the demanded quality, customization given by $|i_j - r|$ is required. As an example, consider the audit firm's implemented audit approach.[54] Downsizing the audit approach to clients demanding lower quality means serving a client on the right, i.e., $r > i_j$, $j \in \{1, 2\}$. As can be infered from equation (1) audit costs increase, because of client attributes imperfectly fitting to the implemented audit approach. For example,

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[53]In general, for a Hotelling setting with three competitors an equilibrium solution cannot be guaranteed, cf. *Economides* (1993) or *Eaton* (1972, p. 269 and 276). Assuming $i_3 = 1$ solves this problem.

[54]See E&Y's webpage labeling the audit approach the „Global Audit Methodology (GAM)" or KPMG's webpage where the lable „Business Audit" is used.

the client may have a less sophisticated internal control system, increasing the required audit effort to generate reliable data or the audit firms might spent more time preparing client's data for the audit process in general. Similarly, upsizing the audit approach means serving a client on the left, i.e., $r < i_j$, $j \in \{1, 2, 3\}$. The cost increase can be explained by clients deserving special audit tasks or higher levels of audit validity, as in regulated industries like banking and insurance. Thirdly, depending upon the ex ante chosen supply-side quality level, the auditors flexibility, θ_j, varies. This parameter captures how efficient or flexible the quality level of the firm can be customized; $\theta_1 < \theta_2 < \theta_3$ is assumed. Even though more experienced auditors cause higher hourly costs, their multifaceted knowledge enables them to react flexibly, substantiating the higher variable costs, $\frac{1}{i_j}$. In summary, total audit costs differ depending on the auditor's quality choice, i_j, and the clients quality demands, r, see Figure 4.
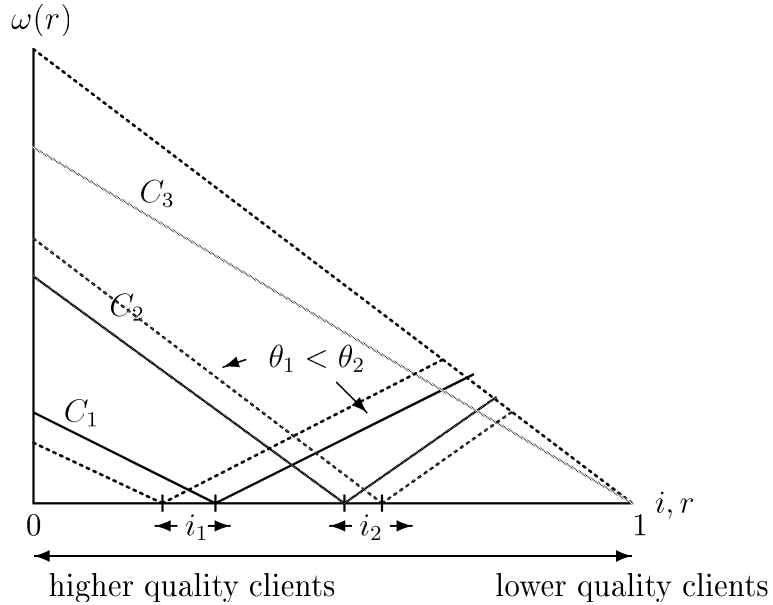

Fig. 4: Impacts of position on audit costs

3.2 Strategic positioning of high quality auditors and mid-tier auditors in a three quality segment setting

Auditors' positioning choice determines the achieveable profit. Cost functions and revenue functions arise from the market segmentation according to the assignment of clients to auditors. Define $r_{1,2}$ as the client's position who is indifferent between appointing the high quality auditor or the mid-tier auditor; define $r_{1,3}$ and $r_{2,3}$ analogously. As these indifference points completely describe the audit market segmentation, we start with deriving them first. Technically, $r_{1,2}$ is the intersection of the high quality audit cost

function, C_1, with the one of a mid-tier firm, C_2:

$$\theta_1(r_{1,2} - i_1)\frac{1}{i_1} = \theta_2(i_2 - r_{1,2})\frac{1}{i_2}$$

$$\Leftrightarrow r_{1,2} = \frac{i_1 i_2(\theta_2 + \theta_1)}{i_1\theta_2 + i_2\theta_1} \tag{2}$$

Similarly, the other intersections, $r_{1,3}$ and $r_{2,3}$ can be determined:

$$r_{1,3} = \frac{i_1 i_3(\theta_3 + \theta_1)}{i_1\theta_3 + i_3\theta_1} \tag{3}$$

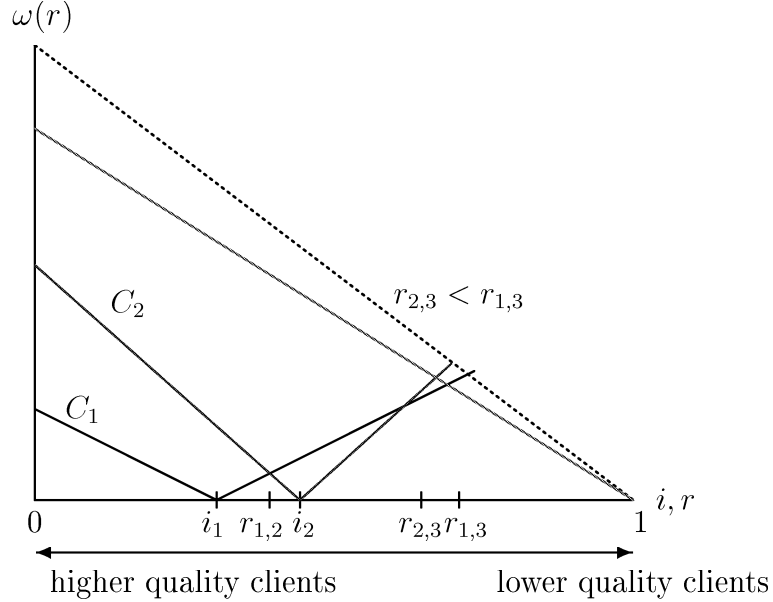$$r_{2,3} = \frac{i_2 i_3(\theta_2 + \theta_3)}{i_2\theta_3 + i_3\theta_2} \tag{4}$$

Fig. 5: $r_{2,3} < r_{1,3}$

Lemma 3.1 *Define $r_{1,2}$, $r_{1,3}$ and $r_{2,3}$ as given by equations (2)-(4). Then, $r_{1,2} < r_{1,3} <$* $r_{2,3}$.

Proof: See Appendix A.

Therefore, we can exlude a situation as depicted in Figure 5, ensuring we can restrict our analysis to situations as depicted in Figure 6. As a result of lemma 3.1 the market segments are convex sets meaning that three distinct assignments of clients to auditors exist.[55] Further, this implies that if an audit firm's bid for a client falls short of another auditor's bid, the client engages the lower priced one.

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[55]Note, Lemma 3.1 does not ensure that the intersections, r_{ih}, lie below the willingness to pay. However, we can exclude this problem, because it means a client is not able to hire an auditor, contradicting our assumption of mandatory audits.
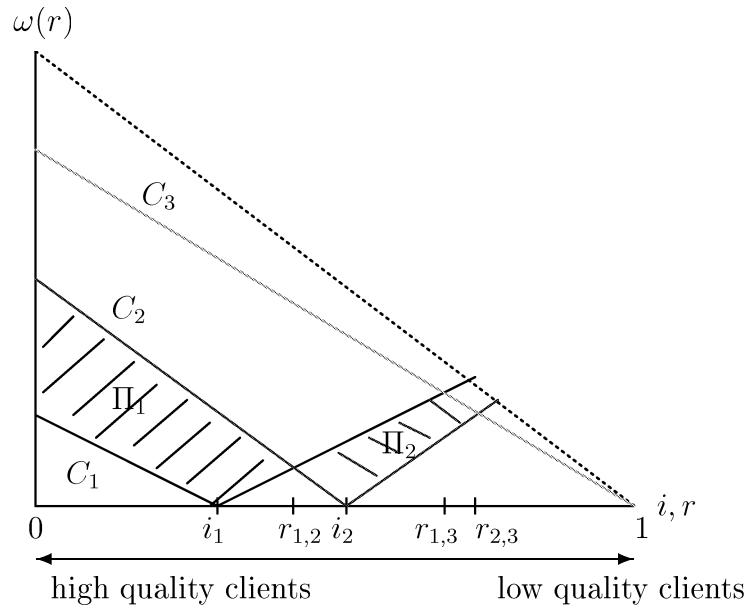
Fig. 6: Profit maximization choice

3.2.1 The impact of mid-tier auditors on competition in a three auditor setting

Selecting an audit quality level as depicted in Figure 6 means taking into account the obtainable profits, subject to the accessible market share, the own position determining the costs for auditing a certain client and the competitors' position choice determining the fees. The high quality and the mid-tier auditors anticipate how their simultaneous choice of location affects their profit function.[56]

Due to the strategic interaction of high quality firms and mid-tier firms deriving the equilibrium requires analyzing the respective reaction functions, $i_1(i_2)$ and $i_2(i_1)$. Maximizing the high quality auditors profit, Π_1, as shown in Figure 6 warrants a differentiation with respect to the quality choice i_1. This results in the high quality auditor's reaction function as stated in Proposition 3.2.1.

Proposition 3.2.1 *The high quality auditors reaction function is:*

$$i_1(i_2) = \frac{\frac{\theta_1+\theta_2}{\sqrt{2}} - \theta_1}{\theta_2} i_2 \qquad (5)$$

Proof: See Appendix B.

The mid-tiers reaction function, $i_2(i_1)$ is derived analogously.

Proposition 3.2.2 *The mid-tier auditors reaction function can be described by the fol-*

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[56]Cf. *Mayhew/Wilkins* (2003, p. 34): "When the audit firm does not differentiate itself significantly from competitors, it loses bargaining power with the client; as a result, competitive pressures will require the audit firm to share its market share-driven cost savings with the client."

lowing equation:

$$i_2(i_1) = \sqrt{\frac{1}{2}r_{2,3}^2(i_2) + \frac{1}{2}r_{1,2}^2(i_1, i_2)} \tag{6}$$

Proof: See Appendix C.

Solving equations (5) and (6) simultaneously gives the equilibrium solution.

Proposition 3.2.3 *The optimal quality choice of the mid-tier auditor is:*

$$i_2^* = \left[\frac{\theta_2 + \theta_3}{\sqrt{\alpha}} - 1\right]\frac{\theta_2}{\theta_3} \text{ with } \alpha = (\theta_1 + \theta_2)\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right] \tag{7}$$

Proof: See Appendix D.

Deriving i_1^* completes deriving the equilibrium conditions.

Proposition 3.2.4 *The high quality auditor's optimal quality choice is:*

$$i_1^* = \frac{\left(\frac{\theta_1 + \theta_2}{\sqrt{2}} - \theta_1\right)\left(\frac{\theta_2 + \theta_3}{\sqrt{(\theta_1 + \theta_2)((2\sqrt{2}-3)\theta_1 + \theta_2)}} - 1\right)}{\theta_3} \tag{8}$$

Proof: Inserting i_2^* as given in Proposition 3.2.3 in 3.2.1 completes the proof.

From a regulatory perspective the average supply-side quality is an important item. In our model, the average supply-side quality is proxied by Ψ. Having determined the market's quality segmentation, the average supply-side quality is defined as the quality level weighted by the market share:

$$\Psi_{(1)} = r_{1,2}i_1 + (r_{2,3} - r_{1,2})i_2 + (1 - r_{2,3})i_3 \tag{9}$$

$$= \frac{i_1 i_2(\theta_1 + \theta_2)}{i_1\theta_2 + i_2\theta_1}\underbrace{(i_1 - i_2)}_{<0} + \frac{i_2(\theta_2 + \theta_3)}{i_2\theta_3 + \theta_2}(i_2 - 1) + 1 \tag{10}$$

Figure 7 exhibits an illustration of the average supply-side quality in a three quality segment setting. Note, no parameters have to be set. Thus, Figure 7 is a general representation of average audit market quality. The graphical illustration shows that the average supply-side quality, $\Psi_{(1)}$, lies in the range between $[0.57, 0.70]$ for variations of θ_1 and θ_2 in $[0,1]$ and $\theta_1 < \theta_2$. For ease of presentation we assume $\theta_3 = 1$. From the results we can conclude that the average supply-side quality seems to be restricted by a lower limit. Considering national audit markets, determining this quality measure might provide insights on the provided quality level at hand as well as changes in the near future.

Given the optimal solutions in equations (3.2.3) and (3.2.4), we analyze in the following section how changes in the audit profession regulation increasing audit costs, potentially have an effect on the audit market structure. Significant changes in the audit pro-
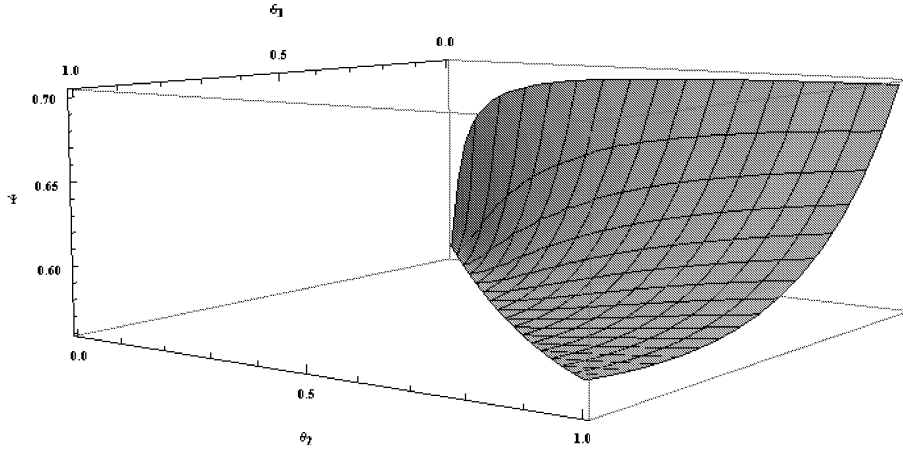
Fig. 7: Graphical illustration of the average supply-side quality

fession also influenced the audit market. In consequence of these SOA-changes new costs were imposed on auditors. However, the incremental costs vary for the audit firms and are assumed to be overproportional for local and regional ones in comparison with international audit firms.[57] Whether tightening regulatory measures has a counter-productive effect on the audit market and provided quality, will be considered by comparative statics in the next section.

3.2.2 Comparative statics and numerical illustration

In Table 3 we consider comparative statistics of the optimal location solutions for i_1 and i_2. Changes in the flexibility parameter θ_j, i.e. customizing the audit approach according to clients needs, influence the audit quality choice and result in a differing segmentation of the audit market. The comparative statics for the mid-tier firm shows that increasing θ_1, i.e.

COMPARATIVE STATICS ANALYSIS[58]

	$\theta_1 \uparrow$	$\theta_2 \uparrow$
i_1	$\frac{\partial i_1}{\partial \theta_1} < 0, i_1 \downarrow$	$\frac{\partial i_1}{\partial \theta_2} < 0, i_1 \uparrow$
i_2	$\frac{\partial i_2}{\partial \theta_1} < 0, i_2 \downarrow$	$\frac{\partial i_2}{\partial \theta_2} > 0, i_2 \uparrow$

Tab. 3: Summary of comparative statics analyis

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[57] Cf. *Read/Rama/Raghunandan* (2004, p. 253).

[58] The derivatives are given in the appendix F. Regarding comparative statics for the lowest quality level, the effect remains unclear. Therefore, we do not include the third quality segment. However, fixing the

the high quality supplier gets less efficient in adopting its audit programm, implies that the mid-tier firm raises the quality level. Interpreting recent changes of the post-SOX period, mainly high quality firms suffered from increasing restrictions with respect to highly qualitative audits. The mid-tier firm strategically relocates to the left $[0, 1]$, consequently, i_2 decreases. Changes in the regulatory environment would contribute to audit market competition and strengthen the mid-tier auditors role. However, if the flexibility of the mid-tier one's in customizing the audit programm decreases, i.e., θ_2 goes up and the mid-tier firm faces greater difficulties in fitting the audit programm to clients, it will move to the right for avoiding competition with the high quality supplier.

Considering the high quality firm, a loss in the flexibility entails a shift to the left preventing from competition with the mid-tier firm. Contrarily, decreasing the mid-tier firm's flexibility causes the high quality supplier to relocate closer to one and thereby increasing competition with the low quality audit firm.

For ease of presentation Table 4 gives a numerical example to illustrate the results of our audit market segmentation approach and its interpretation. Only the flexibility parameters θ_j must be defined exogenously. Given $\theta_1 = 0.3, \theta_2 = 0.8$ and $\theta_3 = 1$ we get the auditor's optimal quality choice following equations (7) and (8). The high quality supplier captures a market share of $r_{1,2} = 0.6647$, while the mid-tier firm's market share gets $r_{2,3} - r_{1,2} = 0.2283$. With respect to the cost component $\frac{1}{i_j}$, the effect of the differentiated supply-side quality gets obvious. The example demonstrates that a highly skilled and educated auditor's wage is higher than a less experienced one's. According to the 'market power' hypothesis, the numerical results exhibit high profits for the high quality supplier according to a great market share.

3.3 Strategic positioning of a high quality auditor in a two quality segment setting

The objective of this paper is to focus on the competitive role of the mid-tier firms and changes of market segmentation in case of the mid-tier firms leaving the market. Lying in between, mid-tier firms compete with high as well as low quality auditors and if there were a voluntarily or a non-voluntarily withdrawal of mid-tier companies – perhaps due to a changing regulatory environment or in response to the competitive environment – the audit market segmentation changes. Based on the necessity to register with the PCAOB, mainly regional and local audit firms resigned from audit engagements.[59] Further enhancing these tendencies, only two quality segments would remain, as replacing a lower

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lowest quality supplier of audit services at $i_3 = 1$ for ensuring mandatory auditing, it does not not matter at all.

[59]Cf. *Read/Rama/Raghunandan* (2004, p. 254).

Efficiency of customizing the audit approach:

$\theta_1 = 0.3$ $\qquad$ $\theta_2 = 0.8$ $\qquad$ $\theta_3 = 1$

Position of high and mid-tier auditors:

$i_1^* = 0.470$ $\qquad$ $i_2^* = 0.787$ $\qquad$ $i_3 = 1$

Audit Cost Parameters:

$\frac{1}{i_1^*} = 2.13$ $\qquad$ $\frac{1}{i_2^*} = 1.27$ $\qquad$ $\frac{1}{i_3} = 1$

Boundaries of market segmentation:

$r_{1,2} = 0.6647$ $\quad$ $r_{1,3} = 0.794$ $\qquad$ $r_{2,3} = 0.893$

Profits in the audit market segments:

$\Pi_1 = 0.225$ $\quad$ $\Pi_2 = 0.024$ $\qquad$ $\Pi_3 = 0$ $\qquad$ $\sum_j \Pi_j = 0.26$

Average audit quality:

$\Psi_{(1)} = 0.599$

Tab. 4: Example of audit market segmentation - three quality levels

quality audit firm exiting the audit market with a high quality one seems too costly.[60] For these reasons we restrict our analysis on the strategic behaviour of the high quality audit firm if mid-tier firms withdrawed from the market. Only the low quality level auditor still offers audit services, but mandatory auditing ensures this auditor remains at $i_3 = 1$.

Deriving the high quality auditors profit, Π_1, compels a differentiation with respect to i_1 and gives the optimal quality level choice summarized in Proposition 3.3.1.

Proposition 3.3.1 *The auditors optimal location choice is:*

$$i_1^* = \frac{(1 - \sqrt{3})\theta_1 + \theta_3}{\sqrt{3}\theta_3} \tag{11}$$

Proof: See Appendix E.

The comparative statics in Tabular 5 yields similar results compared to Table 3. An increase in θ_1 implies a loss of efficiency in customizing the audit approach, the high quality supplier relocates closer to zero.

COMPARATIVE STATICS ANALYSIS II[61]

	$\theta_1 \uparrow$	$\theta_3 \uparrow$
i_1	$\frac{\partial i_1}{\partial \theta_1} < 0, i_1 \downarrow$	$\frac{\partial i_1}{\partial \theta_3} > 0, i_1 \uparrow$

Tab. 5: Summary of comparative statics analyis II

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[60]Cf. *Dunmore/Falk* (2001, p. 313).

[61]See Appendix G

Determining the average supply-side quality for the two quality segmentation yields:

$$\Psi_{(2)} = r_{1,3}i_1 + (1 - r_{1,3}) \qquad (12)$$

$$= \frac{(2 - 2\sqrt{3})\theta_1 i_1 \theta_3 + (1 - \sqrt{3})i_1 \theta_1^2 + \theta_3^2 i_1 + \sqrt{3}\theta_3 \theta_1}{\sqrt{3}\theta_3(i_1 \theta_3 + \theta_1)} \qquad (13)$$

Following equations (9) and (12) we compare both market settings by example. Table 6 illustrates the results for the two quality setting. The high quality auditor's choice in a two quality segment is given by (11). Comparing the results in Tables 4 and 6, one can

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2 QUALITY SEGMENTATION

Efficiency of customizing the audit approach:

$\theta_1 = 0.3 \qquad \theta_3 = 1$

Position of high quality auditor:

$i_1^* = 0.451$

Audit Cost Parameters:

$\frac{1}{i_1^*} = 2.22 \qquad \frac{1}{i_3} = 1$

Boundaries of market segmentation:

$r_{1,3} = 0.781$

Profits in the audit market segments:

$\Pi_1 = 0.372 \qquad \Pi_3 = 0$

Average audit quality:

$\Psi_{(2)} = 0.571$

Tab. 6: Example of audit market segmentation - two quality levels

easily see that the average supply-side quality improves as $\Psi_{(2)} < \Psi_{(1)}$. The high quality firm shifts closer to zero, i.e. closer to the clients seeking a more demanding audit quality. This comes along with an increase in the hourly audit costs as $\frac{1}{i_1}$ increases compared to numerical results in Table 4. Upsizing the audit approach causes less costs, such that the high quality supplier's profit increases and might partly offset the benefits of higher average audit quality.

4 Summary and regulatory implications

The changing audit environment can be characterized by tendencies of concentration and competition for audit assignments. Regulating authorities are confronted with the problem of enabling mid-tier firms to serve large multinational clients. The 'too-big-to-fail' hypothesis captures this governmental's dilemma. In case of observed low audit quality, taking legal actions might consolidate the audit market even further. In the opposite,

taking no legal actions signals the ligitation risk – guaranteeing audit quality – seems not to be enforceable. However, especially mid-tier firms suffer from preserving market shares as they compete with high and low quality auditors. In our modelling approach we analyze the competitive impact of mid-tier audit firms on the audit market segmentation and audit quality. The analyses focuses on strategic quality choices of high and mid-tier audit firms. Analyzing quality differentation of auditing, the model contributes to eplaining the alignment of clients' needs and audit firms' offered qualities. Besides, the analyis of audit market segmentation allows to infer on the interdependencies between market share and profit.

As the intensity of competition and the effects on audit quality cannot be inferred from concentration ratios only, our modelling apporach provides a theoretical basis for analyzing audit market segmentation. Firstly, we are able to form expectations on fee changes as a consequence of changing market shares, supporting either the 'market power'-hypothesis or the 'competition'-hypothesis. Secondly, we can derive predictions on how audit quality depends on market shares and market concentration. Thirdly, taking into account that in some EU-member states the mid-tier auditors are virtually extinct, our model results could serve as starting point of hypotheses for comparing the European audit markets with respect to overall audit quality. Lastly, if the mid-tier firms left the audit market, according to the 'market power' hypothesis audit fees would rise along with an increase in the average supply-side audit quality.

A Proof of Lemma 3.1

$$r_{1,3} = \frac{i_1 i_3 (\theta_1 + \theta_3)}{i_1 \theta_3 + \theta_1} \quad < \quad \frac{i_2 i_3 (\theta_2 + \theta_3)}{i_2 \theta_3 + \theta_2} = r_{2,3}$$

$$\Leftrightarrow \frac{i_1 \theta_1 + i_1 \theta_3}{i_3 \theta_1 + i_1 \theta_3} \quad < \quad \frac{i_2 \theta_2 + i_2 \theta_3}{i_3 \theta_2 + i_2 \theta_3}$$

Define $a = i_1 \theta_1$, $b = i_3 \theta_1$, $c = i_1 \theta_3$, $d = i_2 \theta_2$, $e = i_3 \theta_2$ and $f = i_2 \theta_3$. Note that $c < f$ because per definition $i_1 < i_2$.

$$\frac{i_1}{i_3} = \frac{a}{b} \quad < \quad \frac{d}{e} = \frac{i_2}{i_3}$$

$$\Rightarrow_{(c<f)} \frac{a+c}{b+c} \quad < \quad \frac{d+f}{e+f} \quad \text{qed}$$

Note that $r_{1,2} < r_{1,3} \Leftrightarrow \theta_2 < \theta_3$.

B Proof of Proposition 3.2.1

The high quality auditor's profit function is defined by substracting the own costs, $C_1(r)$, from the attainable fees equaling the competitor's costs, $C_2(r)$, over the interval $[0, r_{1,2}]$.

$$\begin{aligned}
\Pi_1(i_1, i_2) &= \int_0^{r_{1,2}} \frac{\theta_2}{i_2}(i_2 - r)dr - \int_0^{i_1} \frac{\theta_1}{i_1}(i_1 - r)dr - \int_{i_1}^{r_{1,2}} \frac{\theta_1}{i_1}(r - i_1)dr \\
&= -\frac{\theta_2}{2i_2}(i_2 - r_{1,2})^2 + \frac{\theta_2}{2}i_2 - \frac{\theta_1}{2}i_1 - \frac{\theta_1}{2i_1}(r_{1,2} - i_1)^2
\end{aligned}$$

Deriving $\Pi_1(i_1, i_2)$ with respect to i_1 gives the high quality auditors reaction function $i_1(i_2)$:

$$\frac{\partial \Pi_1(i_1, i_2)}{\partial i_1} = \frac{\theta_2}{i_2}(i_2 - r_{1,2})\frac{\partial r_{1,2}}{\partial i_1} - \frac{\theta_1}{2} - \frac{1}{2}\theta_1 \left[\frac{2(r_{1,2} - i_1)(\frac{\partial r_{1,2}}{\partial i_1} - 1)i_1 - (r_{1,2} - i_1)^2}{i_1^2} \right] = 0 \quad (14)$$

From equation (2) is known:

$$\frac{\theta_1}{i_1}\frac{i_2}{\theta_2}(r_{1,2} - i_1) = (i_2 - r_{1,2}) \quad \quad (15)$$

Substituting equation (15) in (14) gives:

$$\Leftrightarrow \quad \frac{\theta_2}{i_2}\left(\frac{\theta_1}{i_1}\frac{i_2}{\theta_2}(r_{1,2}-i_1)\right)\frac{\partial r_{1,2}}{\partial i_1} - \frac{\theta_1}{2} - \frac{1}{2}\theta_1\left[\frac{2(r_{1,2}-i_1)(\frac{\partial r_{1,2}}{\partial i_1}-1)i_1-(r_{1,2}-i_1)^2}{i_1^2}\right] = 0$$

$$\Leftrightarrow \quad \theta_1(r_{1,2}-i_1)\frac{\partial r_{1,2}}{\partial i_1}i_1 - \frac{\theta_1}{2}i_1^2 + \frac{\theta_1}{2}(r_{1,2}-i_1)^2 + \theta_1(r_{1,2}-i_1)i_1 - \theta_1(r_{1,2}-i_1)\frac{\partial r_{1,2}}{\partial i_1}i_1 = 0$$

$$\Leftrightarrow \quad \frac{\theta_1}{2}r_{1,2}^2 - \theta_1 i_1^2 = 0$$

$$\Leftrightarrow \quad i_1 = \frac{1}{\sqrt{2}}\frac{i_1 i_2(\theta_1+\theta_2)}{i_1\theta_2+i_2\theta_1}$$

$$\Leftrightarrow \quad i_1 = \frac{\frac{\theta_1+\theta_2}{\sqrt{2}}-\theta_1}{\theta_2}i_2 \quad \text{qed}$$

C Proof of Proposition 3.2.2

The profit function, $\Pi_2(i_1,i_2)$, for the mid-tier firm reads:

$$
\begin{aligned}
\Pi_2 &= \int_{r_{1,2}}^{r_{1,3}}\frac{\theta_1}{i_1}(r-i_1)dr - \int_{r_{1,2}}^{i_2}\frac{\theta_2}{i_2}(i_2-r)dr - \int_{i_2}^{r_{1,3}}\frac{\theta_2}{i_2}(r-i_2)dr \\
&\quad + \int_{r_{1,3}}^{r_{2,3}}\theta_3(1-r)dr - \int_{r_{1,3}}^{r_{2,3}}\frac{\theta_2}{i_2}(r-i_2)dr \\
&= \frac{\theta_1}{2i_1}\left[(r_{1,3}-i_1)^2-(r_{1,2}-i_1)^2\right] + \frac{\theta_3}{2}\left[(1-r_{1,3})^2-(1-r_{2,3})^2\right] \\
&\quad - \frac{\theta_2}{2i_2}\left[(r_{2,3}-i_2)^2+(i_2-r_{1,2})^2\right]
\end{aligned}
$$

Differentiating $\Pi_2(i_1,i_2)$ with respect to i_2 gives:

$$
\begin{aligned}
\frac{\partial \Pi_2(i_1,i_2)}{\partial i_2} &= -\frac{\theta_1}{i_1}(r_{12}-i_1)\frac{\partial r_{12}}{\partial i_2} - \frac{\theta_2}{2}\left[\frac{2(i_2-r_{12})(1-\frac{\partial r_{12}}{\partial i_2})i_2-(i_2-r_{12})^2}{i_2^2}\right] \\
&\quad + \theta_3(1-r_{23})\frac{\partial r_{23}}{\partial i_2} - \frac{\theta_2}{2}\left[\frac{2(r_{23}-i_2)(\frac{\partial r_{23}}{\partial i_2}-1)i_2-(r_{23}-i_2)^2}{i_2^2}\right]
\end{aligned}
$$

Substituting $(r_{1,2}-i_1) = \frac{\theta_2}{i_2}\frac{i_1}{\theta_1}(i_2-r_{1,2})$ and $(1-r_{2,3}) = \frac{\theta_2}{i_2\theta_3}(r_{2,3}-i_2)$ gives:

$$\frac{\partial \Pi_2(i_1,i_2)}{\partial i_2} = -i_2^2 + \frac{1}{2}\left[r_{2,3}^2+r_{1,2}^2\right] \tag{16}$$

D Proof of Proposition 3.2.3

Inserting $r_{1,2}$ and $r_{2,3}$ in (16), canceling out i_2^2 and multiplying with the denominator gives:

$$2(i_2\theta_3+\theta_2)^2(i_1\theta_2+i_2\theta_1)^2 - i_1^2(\theta_1+\theta_2)^2(i_2\theta_3+\theta_2)^2 - (\theta_2+\theta_3)^2(i_1\theta_2+i_2\theta_1)^2 = 0 \tag{17}$$

Inserting the reaction function $i_1(i_2)$ as given in Proposition 3.2.1 yields

$$i_2^* = \frac{\theta_2(\theta_1 + \theta_2)\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right] + \sqrt{\theta_2^2(\theta_1 + \theta_2)(\theta_2 + \theta_3)^2\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right]}}{(\theta_1 + \theta_2)\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right]\theta_3}$$

Define $\alpha = (\theta_1 + \theta_2)\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right]$, then i_2^* simplifies to:

$$i_2^* = \left[\frac{\theta_2 + \theta_3}{\sqrt{\alpha}} - 1\right]\frac{\theta_2}{\theta_3} \quad \text{qed}$$

E Proof of proposition 3.3.1

$$\frac{\partial P_{1'}}{\partial i_1} = \theta_3(1 - r_{1,3})\frac{\partial r_{1,3}}{\partial i_1} - \theta_1 - \frac{\theta_1}{2}\left[\frac{2(r_{1,3} - i_1)(\frac{\partial r_{1,3}}{\partial i_1} - 1)i_1 - (r_{1,3} - i_1)^2}{i_1^2}\right] \overset{!}{=} 0 \qquad |\cdot i_1^2$$

$$\Leftrightarrow \quad \theta_3\frac{\theta_1}{\theta_3 i_1}(r_{1,3} - i_1)\frac{\partial r_{1,3}}{\partial i_1}i^2 - \theta_1 i_1^2 - i_1\theta_1(r_{1,3} - i_1)\frac{\partial r_{1,3}}{\partial i_1}$$

$$+ \theta_1(r_{1,3} - i_1)i_1 + \frac{\theta_1}{2}(r_{1,3} - i_1)^2 = 0$$

$$\Leftrightarrow \quad -\theta_1 i_1^2 + \theta_1 r_{1,3}i_1 - \theta_1 i_1^2 + \frac{\theta_1}{2}(r_{1,3}^2 - 2r_{1,3}i_1 + i_1^2) = 0 \qquad | : \theta_1$$

$$\Leftrightarrow \quad -2i_1^2 + 0.5r_{1,3}^2 + 0.5i_1^2 = 0$$

$$\Leftrightarrow \quad 3i_1^2 = r_{1,3}^2$$

$$\Leftrightarrow \quad i_1 = \frac{i_1(\theta_1 + \theta_3)}{\sqrt{3}(i_1\theta_3 + \theta_1)}$$

$$\Leftrightarrow \quad i_1 = \frac{(\theta_1 + \theta_3) - \sqrt{3}\theta_1}{\sqrt{3}\theta_3}$$

F Comparative Statics

$$i_2^* = \left[\frac{\theta_2 + \theta_3}{\sqrt{\alpha}} - 1\right]\frac{\theta_2}{\theta_3}; \qquad \alpha = (\theta_1 + \theta_2)\left[(2\sqrt{2} - 3)\theta_1 + \theta_2\right]$$

$$= \frac{\theta_2}{\theta_3}\left(\frac{\theta_2 + \theta_3}{(-0.17\theta_1^2 + 0.83\theta_1\theta_2 + \theta^2)_2} - 1\right)$$

$$\frac{\partial i_2^*}{\partial \theta_1} = \frac{\theta_2}{\theta_3}\left(\frac{-(\theta_2 + \theta_3)\underbrace{\left(2\theta_1(2\sqrt{2} - 3) + \theta_2(1 + 2\sqrt{2} - 3)\right)}_{>0}}{\underbrace{\alpha^2}_{>0}}\right) < 0$$

$$\frac{\partial i_2}{\partial \theta_2} = \frac{1}{\theta_3}\left(\frac{(\theta_2+\theta_3)}{-0.17\theta_1^2+0.83\theta_1\theta_2+\theta_2^2}-1\right)+\frac{\theta_2}{\theta_3}\left[\frac{(-0.17\theta_1^2+0.83\theta_1\theta_2+\theta_2^2)-(\theta_2+\theta_3)(0.83\theta_1+2\theta_2)}{(-0.17\theta_1^2+0.83\theta_1\theta_2+\theta_2^2)^2}\right.$$

$$= -\frac{1}{\theta_3}+\frac{\theta_3}{\theta_3}\frac{1}{\alpha}+\frac{\theta_2}{\theta_3}\frac{1}{\alpha}-\frac{\theta_2}{\theta_3}\frac{(\theta_2+\theta_3)(0.83\theta_1+2\theta_2)}{(-0.17\theta_1^2+0.83\theta_1\theta_2+\theta_2^2)^2}$$

$$= \frac{\theta_2+\theta_3}{\theta_3}\frac{1}{\alpha}-\frac{1}{\theta_3}-\frac{\theta_2+\theta_3}{\theta_3}\frac{\overbrace{0.83\theta_1\theta_2+2\theta_2^2}^{>\alpha}}{\alpha^2}$$

$$\frac{\partial i_2}{\partial \theta_2}>0 \iff \frac{\theta_2+\theta_3}{\theta_3}\frac{1}{\alpha}>\frac{1}{\theta_3}+\frac{\theta_2+\theta_3}{\theta_3}\frac{0.83\theta_1\theta_2+2\theta_2^2}{\alpha^2}$$

$$\iff \frac{\theta_2+\theta_3}{\theta_3}>\frac{\alpha}{\theta_3}+\frac{\theta_2+\theta_3}{\theta_3}\frac{0.83\theta_1\theta_2+2\theta_2^2}{\alpha}$$

$$\iff \frac{\theta_2+\theta_3}{\theta_3}>\frac{\alpha}{\theta_3}+\frac{\theta_2+\theta_3}{\theta_3}\underbrace{\frac{0.83\theta_1\theta_2+2\theta_2^2}{-0.17\theta_1^2+0.83\theta_1\theta_2+\theta_2^2}}_{>1}$$

$$\frac{\partial i_1}{\theta_1}=\left(\underbrace{\frac{1}{\sqrt{2}}-1}_{<0}\right)\frac{i_2}{\theta_2}+\alpha\cdot\underbrace{i_2'}_{<0}<0$$

$$i_1 = \underbrace{\frac{\frac{\theta_1+\theta_2}{\sqrt{2}}-\theta_1}{\theta_2}}_{\beta(\theta_1,\theta_2)}\cdot i_2(\theta_1,\theta_2,\theta_3)$$

$$= \beta(\theta_1,\theta_2)(i_2(\theta_1,\theta_2,\theta_3)$$

$$\frac{\partial i_1}{\partial \theta_1} = \frac{\partial \beta}{\partial \theta_1}i_2(\cdot)+\beta(\cdot)\frac{\partial i_2}{\partial \theta_1}$$

$$= \frac{i_2}{\theta_2}(\frac{1}{\sqrt{2}}-1)+\beta\frac{\partial i_2}{\partial \theta_1}<0$$

$$\frac{\partial i_1}{\theta_2} = \frac{\partial \beta}{\partial \theta_2}i_2(\cdot)+\beta(\cdot)\frac{\partial i_2}{\partial \theta_2}$$

$$= \frac{\frac{1}{\sqrt{2}}\theta_2-\left[\frac{\theta_++\theta_2}{\sqrt{2}}-\theta_1\right]}{\theta_2^2}$$

$$= \frac{\theta_1(1-\frac{1}{\sqrt{2}})}{\theta_2^2}$$

G Comparative Statics II

$$i_1^* = \frac{(1 - \sqrt{3})\theta_1 + \theta_3}{\sqrt{3}\theta_3}$$

$$\frac{\partial i_1}{\partial \theta_1} = \frac{(1 - \sqrt{3})}{\sqrt{3}\theta_3} < 0$$

$$\frac{\partial i_1}{\partial \theta_2} = \frac{(\sqrt{3} - 1)\theta_1}{\sqrt{3}\theta_3^2} > 0$$

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