Rising and Changing Professional Knowledge as Barriers to Entry

Shmuel Nitzan, PhD
Economics Department, Bar Ilan University, Israel
+972-50-7252279
nitzans@mail.biu.ac.il

Uriel Procaccia, PhD
Faculty of Law, Interdisciplinary Center, Israel, and
and the Center for the Study of Rationality, Hebrew University, Israel.
+972-52-4668696
uriel.procaccia@idc.ac.il

Joseph Tzur, PhD, CPA (Is)
Ruppin Academic Center, Israel.
+972-52-3396033
zur.yosi@gmail.com

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ABSTRACT

Applying a partial equilibrium model, this paper examines the role of the rate of increase in the level of professional knowledge and the role of the rate of replacement of "old" for "new" knowledge on the equilibrium concentration level in a market for professional services. The two main results provide the conditions for 'no-entry' and 'no-exit' equilibrium. These conditions provide a plausible rationalization for concentration in the high-level market for professional services. In this paper we use data pertaining in particular to the high-level market for auditing services. The generality of our results suggests that a similar model can be utilized to illuminate concentration phenomena in additional markets for professional and related services.

INTRODUCTION

The literature on entry limitations has dealt with adverse selection, moral hazard, advertising and the durability and replacement of capital as barriers to entry, see Dell' Ariccia et al. (1999), Farrell (1986), Nagle (1981) and Eaton and Lipsey (1980). But it has not examined the roles of the volume and pace of changes in the professional knowledge as an entry barrier. The objective of this study is to contribute to this literature by showing how the rate of increase in the level of professional knowledge and the rate of replacement of "old" for "new" knowledge determine the structure (level of concentration) of a market for high-level professional services and, in particular, how they can rationalize an observed tendency of increased concentration. We use the market for two-type (low and high) auditing services.

In the field of Auditing of publicly traded companies, professional knowledge is comprised of (i) knowledge of the GAAP (Generally Accepted Accounting Principles) and (ii) knowledge of regulation pertaining to both the industry and the activities of the client company. Awareness of the potential benefits from changes in GAAP and in regulation (which are usually thought of as salutary regulatory responses to the changing business environment) should be complemented with awareness of the negative effects on market concentration of the volume and pace of changes in the GAAP and in the resulting regulatory requirements.

In our setting, any company is required by law to be audited annually by an independent CPA (Certified Public Accountant), whether its stock or bonds are publicly traded or not. But, when the stock or bonds are traded publicly in a regulated exchange, the accounting rules for that company are different. For example, most private companies in the USA whose shares or bonds are *not* traded in a regulated exchange are using simple and stable 'historical cost' accounting rules for preparing their reports. They do not apply the US GAAP. Some private companies are required by lenders, bonding companies, regulators and others to prepare financial statements conforming to the US GAAP but in many of these cases this requirement is dispensed with if a Certified Public Accountant (CPA) appends her audit with an appropriate reservation.[1]

The International Financial Reporting Standards (IFRS) and, similarly, the US GAAP provide preparers of financial statements with instruction on how to measure assets and liabilities and how to report the changes in their measured amounts. In addition, companies whose shares or debt instruments are publically traded are subject to governmental regulation (e.g., the SEC) that is voluminous and changing over time. Another aspect of professional knowledge is regulation of the client industry (e.g., insurance, banking, tobacco). In this context, professional knowledge refers to familiarity with the IFRS or the US GAAP; with the SEC regulation; and with government regulation of the client industry.

Our partial equilibrium model examines the market for professional services where CPA-firms offer their customers a professional service. There are two groups of customers: low-level and high-level customers. The professional knowledge needed to serve the low-level customers is stable. We assume that all the professionals already have the knowledge to provide the service to the low-level customers and, therefore, the costs of maintaining that knowledge are negligible. In contrast, the professional knowledge needed to serve the high-level customers is increasing over time and, in addition, part of the existing knowledge is updated and replaced each period.

[1] Blue Ribbon Panel on Standard Setting of Private Companies: Report to the Board of Trustees of the Financial Accounting Foundation, January 2011.

It is shown that the rate of increase in the professional knowledge and the rate of knowledge replacement serve as a barrier to entry to the high-level services. A CPA firm that wishes to provide auditing services to publicly traded companies has to bear the costs of (i) entering the market and (ii) maintaining its knowledge. Since these costs are growing over time, the entry cost at some point exceeds the benefit from serving a high-level customer and therefore no new CPA firms enter the high-level market. Also, over time, small CPA firms exit the high-level market. This leads to higher concentration levels where the big CPA firms control the high-level market.

While our study clarifies the roles of the volume and pace of changes in the professional knowledge in determining market structure, it does not offer a political-economic theory that explicitly deals with the endogenous determination of these changes. Nevertheless, it clearly alludes to the possibility that some political players may have an axe to grind in this respect. A fuller integration of this issue awaits further research.

Undoubtedly, in the high-level market of auditing services professional knowledge is highly increasing. Our approach and results can therefore contribute to the understanding of the observed high concentration in this market. Let us briefly describe the situation in this market in UK and the US.

Beattie, Goodacre and Fearnley (2003) documented the concentration in the UK audit market for listed companies from 1968 to 2003. During this period, the number of audit firms active in the market *decreased* steadily from 1,109 audit firms to 84 audit firms. In addition, the percentage of audits performed by the "Big 4" (PriceWaterhouseCoopers, KPMG, Ernst & Young and Deloittc &Touche) CPA firms increased from about 20% to above 70%.

The concentration level in the US market for auditing public companies reached similar levels (see Willekens and Achmadi (2003)). Caban-Garcia and Cammack (2009) report that the "Big 4" CPA firms audited 91% of the US public companies in 2003.

Eichenseher and Danos (1981) studied the causes for different concentration levels of auditors in different industries. They showed that auditor concentration in each industry is positively correlated with the levels of client-industry regulation and capital market activity. In terms of our model, higher levels of client-industry regulation and of capital market activity and specifically the pace of regulation changes imply higher professional knowledge that is needed to serve a client.

Finally, it is interesting to note that in 2012, the total revenues of the "Big 4" CPA firms were reported to exceed 110 billion dollars. [2]

THE MODEL

Stigler (1968 p. 67) defined a barrier to entry as "a cost of producing (at some or every rate of output) that must be borne by firms seeking to enter an industry but is not borne by firms already in the industry." The level of professional knowledge creates a barrier to entry in two ways: (i) it prevents new CPA firms from entering the high-level market; and (2) it drives out of the high-level market small CPA firms that cannot afford to maintain their level of professional knowledge. In other words, the changes in the professional knowledge can be viewed as both "*barrier to entry*" and "*pressure to exit*". [3]

The knowledge needed to provide the service to a high-level customer at time t, $K(t)$, is measured in terms of the cost of acquiring and assimilating this knowledge. We assume that $K(t) = K_0 + D\left(1 - e^{-\beta t}\right)$. At time 0, $K(0) = K_0$ and as t increases, the level of knowledge approaches $K_0 + D$. The rate of change of knowledge is $\frac{dK(t)}{dt} = \beta D e^{-\beta t}$, and $\frac{d^2K(t)}{dt^2} = -\beta^2 D e^{-\beta t}$. Thus, the concavity measure of $K(t)$ is $\frac{d\left[Ln(K'(t)\right]}{dt} = \frac{K''(t)}{K'(t)} = -\beta$.

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[2] *The 2012 Big Four Firms Performance Analysis* http://www.big4.com/wp-content/uploads/2013/01/The-2012-Big-Four-Firms-Performance-Analysis.pdf.

[3] Note that a barrier to entry does not necessarily reduce public welfare. For example, professional knowledge of oncologists is increasing over time and it possibly creates a barrier to enter the market for cancer treatments, but we presume that the increasing knowledge enhances the cure of people. However, in the context of the auditing market it is not clear that higher pace of changes in GAAP and in industry specific regulation is enhance public welfare.

The higher is β, the sooner the level of knowledge approaches its maximum level. The time it takes to reach a level of knowledge which is $K_0 + \delta D$, for $0 < \delta < 1$, is $t = \frac{1}{\beta} Ln\left[\frac{1}{1-\delta}\right]$.

In addition to the growth in the level of knowledge, part of the existing knowledge, α, has to be replaced continuously.

Suppose that a professional who provides service to the low-level market considers entering the high-level market at time *t*. To be able to provide the service, he first has to learn and assimilate the current state of knowledge. In addition, the entering professional has to take into account the present value of the costs to maintain his ability to serve the high- level market. Let the interest rate be denoted by *i.* At time *t*, the present value of the cost of entering the high-level market and stay there is

$$PV(enter - and - stay) = K(t) + \int_t^\infty \left[\beta D e^{-\beta x - i(x-t)} + \alpha K(x) e^{-i(x-t)} \right] dx.$$

Substituting $K(x) = K_0 + D\left(1 - e^{-\beta x}\right)$ into the above equation yields,

$$PV(enter-and-stay)=\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{1}{1+\frac{i}{\beta}}\right)De^{-\beta t}\right).$$ [4]

The effect of time on the entry cost

Notice that $\frac{d}{dt}PV(enter-and-stay)>0$. That is, the entry cost is increasing over time:[5]

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[4] **Proof**

$$PV(enter-and-stay)=K(t)+\int_t^\infty\left[\beta De^{-\beta x-i(x-t)}+\alpha K_0e^{-i(x-t)}+\alpha D\left(1-e^{-\beta x}\right)e^{-i(x-t)}\right]dx=$$

$$K(t)+\int_t^\infty\left[\beta De^{-\beta x-ix+it}+\alpha K_0e^{-i(x-t)}+\alpha De^{-i(x-t)}-\alpha De^{-\beta x-ix+it}\right]dx=$$

$$K(t)+\int_t^\infty\left[\beta D\left(1-\frac{\alpha}{\beta}\right)e^{-\beta x-ix+it}+\left(\alpha K_0+\alpha D\right)e^{-i(x-t)}\right]dx=.$$

$$K(t)+\left[-\frac{\beta D}{\beta+i}\left(1-\frac{\alpha}{\beta}\right)e^{-\beta x-ix+it}-\frac{\alpha}{i}\left(K_0+D\right)e^{-i(x-t)}\right]_{x=t}^{\infty}=$$

$$K(t)+\frac{\beta D}{\beta+i}\left(1-\frac{\alpha}{\beta}\right)e^{-\beta t}+\frac{\alpha}{i}\left(K_0+D\right)$$

Substituting $K_0=K(t)-D\left(1-e^{-\beta t}\right)$ into the above last expression yields,

$$PV(enter-and-stay)=\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{1}{1+\frac{i}{\beta}}\right)De^{-\beta t}\right).$$

[5]

$$\frac{d}{dt}\left[\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{1}{1+\frac{i}{\beta}}\right)De^{-\beta t}\right)\right]=\left(1+\frac{\alpha}{i}\right)\left(\beta De^{-\beta t}-\beta D\left(\frac{1}{1+\frac{i}{\beta}}\right)e^{-\beta t}\right)=$$

$$=\beta D\left(1+\frac{\alpha}{i}\right)e^{-\beta t}\left(1-\left(\frac{1}{1+\frac{i}{\beta}}\right)\right)=\beta De^{-\beta t}\left(1+\frac{\alpha}{i}\right)\left(\frac{1}{1+\frac{i}{\beta}}\right)=\left(\frac{i+\alpha}{i+\beta}\right)\beta De^{-\beta t}>0$$

Therefore, if the benefit from entering the high-level market is stable over time, and at time t_0 the entry cost is a viable barrier to entry, it will continue to be a barrier to entry in the future, for any $t > t_0$.

It is interesting to note that

$$\frac{d}{dt} PV(enter - and - stay) = \left(\frac{i+\alpha}{i+\beta}\right) \beta D e^{-\beta t} = \left(\frac{i+\alpha}{i+\beta}\right) \frac{dK(t)}{dt}.$$

Therefore, the ratio $\dfrac{\frac{d}{dt} PV(enter - and - stay)}{\frac{d}{dt} K(t)} = \dfrac{1+\frac{\alpha}{i}}{1+\frac{\beta}{i}}$ is constant;

If $\alpha > \beta$, then $\dfrac{\frac{d}{dt} PV(enter - and - stay)}{\frac{d}{dt} K(t)} > 1$; that is, the rate of increase in the cost to enter the market is higher than the rate of increase of knowledge.

At $t = 0$, the cost of entering the high-level market is:

$$PV(enter - and - stay)_{t=0} = \left(1+\frac{\alpha}{i}\right)\left(K_0 + \left(\frac{1}{1+\frac{1}{\beta / i}}\right) D\right)$$

The higher the standardized $\frac{\alpha}{i}$ and $\frac{\beta}{i}$, the higher the cost of entering the market.

But the effect of $\frac{\alpha}{i}$ is different from that of $\frac{\beta}{i}$: If $\frac{\alpha}{i} \to \infty$, then $PV(enter - and - stay)_{t=0} \to \infty$, but if $\frac{\beta}{i} \to \infty$, then $PV(enter - and - stay)_{t=0} \to \left(1+\frac{\alpha}{i}\right)\left(K_0 + D\right)$. In other words, the effect of the rate of knowledge replacement on the entry cost is much stronger than the effect of the rate of increase in the knowledge. This is because, in our setting, the knowledge is bounded from above by $K_0 + D$.

As $t \to \infty$, the cost of entering the high-level market is:

$PV(enter-and-stay)_{t\to\infty}=\left(1+\frac{\alpha}{i}\right)\left(K_0+D\right)$. In the long run the entry cost depends on the standardized rate of knowledge replacement $\frac{\alpha}{i}$ and on the maximum level of knowledge, K_0+D.

The total increment in the entry cost is

$$PV(enter-and-stay)_{t\to\infty}-PV(enter-and-stay)_{t=0}=$$

$$\left(1+\frac{\alpha}{i}\right)\left(K_0+D\right)-\left(1+\frac{\alpha}{i}\right)\left(K_0+\frac{\beta}{i+\beta}D\right)=\left(\frac{i+\alpha}{i+\beta}\right)D=\left(\frac{1+\frac{\alpha}{i}}{1+\frac{\beta}{i}}\right)D$$

Notice that *D* is the total increase in the level of knowledge (from K_0 to $K_{t\to\infty}=K_0+D$). Hence, the total increase in the entry cost is directly related to the total increase in the level of knowledge, and it also depends on the standardized rates of knowledge, growth and replacement. Also note that the total increase in the entry cost increases with $\frac{\alpha}{i}$ and decreases with $\frac{\beta}{i}$. The reason for that is that when $\frac{\beta}{i}$ is increased, the cost to enter the high-level market at *t=0* is increased whereas the entry cost when $t\to\infty$ is independent of $\frac{\beta}{i}$.

The benefit from entering the high-level market

Let us denote by N the number of professionals that operate in the high-level market and by p the professional's added income from serving a customer in the high-level market rather than serving other customers in the low-level market. Let g denote the professional's perceived growth rate of the number of his customers from the high- level market. Given the plausible assumption that the perceived growth rate is lower than the interest rate, $g<i$, the

professional's perceived present value of the benefits from entering the high-level market is $\int_{x=t}^{\infty} pe^{(g-i)x}dx = p\left[\frac{e^{(g-i)x}}{g-i}\right]_{x=t}^{\infty} = p\left[0-\frac{1}{g-i}\right] = \frac{p}{i-g}$. [6]

Therefore, the professional's knowledge is a viable barrier to entry, at time *t*, if the benefit from entering the high-level market is lower than the entry cost:

$$\frac{p}{i-g} < \left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}\right).$$

The equilibrium conditions

Denote by n_j the number of customers from the high-level market of professional *j* and denote by N_t the number of professionals in the high-level market at time t.

At *t*, no professional has an incentive to exit the high-level market if, for any $n_j \in \{n_1, n_2, ..., n_{N_t}\}$,

$$\text{(no-exit condition)} \quad \frac{p}{i-g} > \frac{\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)}{n_j}$$

The LHS is the average benefit from a current customer in the high-level market and the RHS is the average cost per customer of maintaining the level of knowledge and make it feasible to serve the customers. Notice that as the number of customers n_j increases, the average cost of knowledge maintenance decreases which, in turn, provides an incentive to stay in the high-level market. And, at time *t*, no professional has an incentive to enter the high-level market if

$$\text{(no-entry condition)} \quad \frac{p}{i-g} < \left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}\right).$$

Hence, in equilibrium, for any $n_j \in \{n_1, n_2, ..., n_{N_t}\}$,

[6] A violation of this assumption, viz., $g > i$, implies infinite benefit from entering the high-level market that, in turn, increases the number of firms that enter the high-level market. Therefore, the actual growth rate decreases, which , in turn, reduces the perceived rate g. This process continues until the assumption is satisfied.

$$\frac{\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)}{n_j}<\frac{p}{i-g}<\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}\right)$$

Denote by n_0 the minimum number of clients for a professional in the high-level market, $n_0 = Min\left\{n_1, n_2, ..., n_{N_t}\right\}$. In equilibrium, where no firm enters or exits the market for high-level services, both conditions must hold at time *t*:

(no-entry condition) $$\frac{p}{i-g}<\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}\right),$$

and,

(no-exit condition) $$\frac{p}{i-g}>\frac{\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)}{n_0}$$

<u>The possibility of equilibrium – the 'no-entry condition'</u>

The "no-entry" condition holds if $NE=\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}\right)-\frac{p}{i-g}>0$

NE denotes the excess of entry cost over the benefit from entering the high-level market.

Since the benefit from entering the high-level market is the same over time, for any fixed interest rate, $\frac{\partial(NE)}{\partial t}=\frac{d}{dt}\left[PV(enter-and-stay)\right]>0$.

Result 1

If the long run cost of entering the high-level market is larger than the benefit, that is, $\left(1+\frac{\alpha}{i}\right)\left(K_0+D\right)>\frac{p}{i-g}$, then there exits t_0 such that for any $t>t_0$, the "no-entry" condition holds.

Proof: See Appendix.

Note that if the perceived growth rate is zero, $g=0$, then the condition for the existence of "no-entry" may be expressed as $\alpha+i>\frac{p}{K_0+D}$. Thus, for any level of interest, it is sufficient that $\alpha>\frac{p}{K_0+D}$. In other words, if the rate of change of professional knowledge is higher than the ratio of the benefit (from serving a client in the high-level market) to cost (of acquiring the knowledge) then at some point of time no professional enter the market for high level services.

The possibility of equilibrium - the "no-exit" condition

If the rate of knowledge replacement is higher (smaller) than the rate of growth of knowledge, that is, $\alpha>\beta \quad (\beta>\alpha)$, then the maintenance cost is increasing (decreasing) over time.[7] In both cases we obtain

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$$\frac{\partial}{\partial t}\left[\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)\right]=-\beta\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}\frac{\partial K(t)}{\partial t}=$$

$$-\beta\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}\frac{\partial}{\partial t}\left(K_0+D\left(1-e^{-\beta t}\right)\right)=$$

$$-\beta\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}\beta De^{-\beta t}=D\beta e^{-\beta t}\frac{\beta}{i}\left[\frac{\alpha}{\beta}-\frac{i+\alpha}{i+\beta}\right]>0$$

Result 2

The no-exit condition is satisfied if $\frac{n_0 p}{i-g} > \frac{\alpha}{i}\left(K_0 + D\right)$.

Proof: See Appendix.

Combining Result 1 and Result 2 , we get that at equilibrium:

$$\frac{\frac{n_0 ip}{i-g}}{K_0 + D} > \alpha > \frac{\frac{ip}{i-g}}{K_0 + D} - i$$

If the expectation for growth is nil, $g = 0$, we get that equilibrium is ensured if :

$$\frac{n_0 p}{K_0 + D} > \alpha > \frac{p}{K_0 + D} - i .$$

Notice that a if $\alpha > \frac{p}{K_0 + D}$ then for any level of interest rate, $\alpha > \frac{p}{K_0 + D} - i$.

Therefore, sufficient conditions for equilibrium are that $\frac{n_0 p}{K_0 + D} > \alpha > \frac{p}{K_0 + D}$.

This last result sheds light on the important role of the rate of changing regulations. The rate, α, must be higher than the ratio of benefit to cost, $\frac{p}{K_0 + D}$, so that an outsider is deterred from entering the market, and the rate of regulation change divided by the minimum number of clients for an incumbent firm, $\frac{\alpha}{n_0}$, must be lower than the ratio of benefit to cost, $\frac{p}{K_0 + D}$, so that an incumbent firm will not exit the market.

Notice that if the regulator (e.g., the Securities and Exchange Commission) imposes new rules that reduce the extra benefit of providing an auditing service to a public company, then this will cause a higher concentration in the professional market. For example, if by a new regulation, an auditor is prohibited from consulting his auditing client on business or tax issues, the benefit from auditing a public company is decreased and thus more CPA firms will exit the high-level market. This process continues until the minimum number of clients is large enough such that $p > \frac{\alpha\left(K_0 + D\right)}{n_0}$. In other words, regulation may cause higher concentration.

The effect of increasing cost to maintain professional knowledge is twofold: (i) it decreases the number of CPA firms that provide service to public companies; and (ii) to cope with the maintenance cost of professional knowledge, the incumbent professionals specialize in providing auditing services to companies in specific areas of knowledge, such as automobiles, high-tech, oil and gas, mining or aerospace and defense. For example, in 2002, 84% of the Oil and Gas industry were audited by E&Y; 100% of the Tobacco industry were audited by PWC; 55% of the Banking industry were audited by KPMG (Beattie, Goodacre and Fearnley, 2003).

CONCLUSION

The sheer volume and velocity of change of both the applicable accounting rules and of the regulatory environment are shown to be a primary cause of market concentration in the high-level auditing market. More specifically, New CPA firms will be hesitant to access this market and numerous existing firms that have too few clients in this market will be forced out for lack of means to master both the volume of the required professional knowledge and its rapid rate of transformation. In addition, regulations that are intended to increase the level of independence of the auditor from the audited company may cause small CPA firms to exit the market. The generality of our results suggests that a similar model can be utilized to illuminate concentration phenomena in additional markets for professional and related services.

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APPENDIX

Proof of Result 1

If $PV(enter-and-stay)_{t=0}=\left(1+\frac{\alpha}{i}\right)\left(K_0+\frac{\beta}{i+\beta}D\right)>\frac{p}{i-g}$ then, because $\frac{\partial(NE)}{\partial t}>0$, for any t, the "no-entry" condition holds**.**

If $NE_{t=0}=\left(1+\frac{\alpha}{i}\right)\left(K_0+\frac{\beta}{i+\beta}D\right)-\frac{p}{i-g}<0$ but $NE_{t\to\infty}=\left(1+\frac{\alpha}{i}\right)\left(K_0+D\right)-\frac{p}{i-g}>0$, then there exist t_0 for which $\left(1+\frac{\alpha}{i}\right)\left(K(t_0)+\left(\frac{\beta}{\beta+i}\right)De^{-\beta t_0}\right)=\frac{p}{i-g}$.

Since $\frac{\partial(NE)}{\partial t}>0$, for any $t>t_0$,

$$NE=\left(1+\frac{\alpha}{i}\right)\left(K(t)+\left(\frac{B}{\beta+i}\right)e^{-\beta t}\right)-\frac{p}{i-g}>0.$$

Therefore, there exits t_0 such that for any $t>t_0$ the "no-entry condition" holds if and only if $\left(1+\frac{\alpha}{i}\right)\left(K_0+D\right)-\frac{p}{i-g}>0.$

Proof of Result 2

Notice that, for any α and β, when $t \to \infty$, the maintenance cost is

$$\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)\to\frac{\alpha}{i}\left(K_0+D\right).$$

Case 1: $\alpha > \beta$

Since the maintenance cost is increasing over time,

$$\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)<\frac{\alpha}{i}\left(K_0+D\right).$$

If $\frac{n_0 p}{i-g}>\frac{\alpha}{i}\left(K_0+D\right)$, then a service provider in the high-level market has no incentive to exit the market, since for any *t*, $\frac{n_0 p}{i-g}>\frac{\alpha}{i}(K_0+D)>\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t).$

If, on the other hand, $\frac{n_0 p}{i-g}<\frac{\alpha}{i}\left(K_0+D\right)$, then there exists some t_0 such that for any $t>t_0$

$\frac{n_0 p}{i-g}<\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)$ and therefore for $t>t_0$ the firm exits the high-level market.

Case 2: $\alpha < \beta$

Since the maintenance cost is decreasing over time,

$$\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t}+\frac{\alpha}{i}K(t)>\frac{\alpha}{i}\left(K_0+D\right).$$

If $\frac{n_0 p}{i-g}>\frac{\alpha}{i}\left(K_0+D\right)$, then there exists t_0 such that for any $t>t_0$,

$\frac{n_0 p}{i-g} > \left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t} + \frac{\alpha}{i}K(t)$. In other words, for $t > t_0$ a service provider in the high-level market has no incentive to exit the market.

If, on the other hand, $\frac{n_0 p}{i-g} < \frac{\alpha}{i}\left(K_0 + D\right)$, then $\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t} + \frac{\alpha}{i}K(t) > \frac{n_0 p}{i-g}$ and the firm exits the high-level market.

Case 3: $\alpha = \beta$

Since the maintenance cost is constant over time, $\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t} + \frac{\alpha}{i}K(t) = \frac{\alpha}{i}\left(K_0 + D\right)$.

If $\frac{n_0 p}{i-g} > \frac{\alpha}{i}\left(K_0 + D\right)$, then $\frac{n_0 p}{i-g} > \left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t} + \frac{\alpha}{i}K(t)$. In other words, a service provider in the high-level market has no incentive to exit the market.

If, on the other hand, $\frac{n_0 p}{i-g} < \frac{\alpha}{i}\left(K_0 + D\right)$, then $\left(1+\frac{\alpha}{i}\right)\left(\frac{\beta}{\beta+i}\right)De^{-\beta t} + \frac{\alpha}{i}K(t) > \frac{n_0 p}{i-g}$ and the firm exits the high-level market.