Price Liberalization and Market Power in Insurance

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October 1993

Abstract

Insurance services have a prominent role in modern societies. Empirical evaluation of market interactions in insurance is, however, scarce. To fill this gap, two models are proposed. Each captures the main features of either regulated or deregulated markets. Three levels of decisions, reinsurance, capacity and prices, generate testable predictions on the exercise of market power.

Recent evolution of the Portuguese market provides a natural experiment for application. Estimation before and after price deregulation reveals a dramatic change in behavior. Coordination has characterized the interaction under price regulation. After deregulation, in contrast, competition between firms has been fierce.

JEL numbers: G22, L13

*I benefited from the comments and suggestions of Luís Cabral, José Machado; José Mata, Tore Nilssen, Maximiano Pinheiro, Paulo Pinho, Rui Monteiro and several seminar participants. Partial financial support from an EC Human Capital Mobility Fellowship, grant # ERB4050PL920219, is gratefully acknowledged. Any remaining deficiencies are my responsibility.
1 Introduction

Insurance services have a prominent role in modern societies, and despite this fact, empirical evaluation of market interactions between insurance companies is scarce. The purpose of this paper is to characterize insurers' decisions, namely the exercise of monopoly power, in a suitable way for empirical measurement.

Attention is devoted to the possible existence of collusion under rate regulation. Regulation of rates is a feature of several insurance markets. Many studies have investigated rate regulation in auto-insurance. Those studies (done mainly for a cross-section of the U.S. states) report, in general, a negative impact in average prices from regulation (prior approval) of rates. On the other hand, a recent study by Finsinger and Schmid (1991) on European insurance markets has found much higher rates in countries with strict government regulation, and also a reduction in concentration in more regulated markets. Anyhow, no structural model, with optimizing behavior by firms, underlies the analysis.

The knowledge of how firms react to price liberalization is also of importance to policymakers, namely in Europe. E.C. legislation is going towards further integration of national markets of state members. The different European countries have had distinct approaches to the insurance business, ranging from essentially free markets to strictly regulated ones. With the openness of borders within the Community, the markets subject to heavier regulation, namely rate regulation (insurance rates set directly by a regulatory body or through a prior approval regime) must face a price liberalization process. The way insurance companies will react to this new environment will decide the evolution of the insurance sector in the forthcoming years.

We attempt to provide a theoretical framework to assess empirically conduct of firms under the two institutional arrangements, with and without rate regulation.

An application to the Portuguese auto-insurance market is reported. The evolution of this market provides a natural example of the issues involved since it changed from a very strict rate regulation regime to a more lenient system of price announcement.

Market conduct changes after entry liberalization have received some attention in the literature, but the relevant issue of change in conduct in response to price deregulation is less investigated. We show some evidence suggesting that such changes can be dramatic.

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1 For a survey, see Harrington (1987).
2 A recent work in this line is Rubioavitz (1993) for the US Cable TV market.
in insurance, once differences in firms’ interactions across regulatory regimes are taken into account.

Recognizing that oligopolistic interaction under price regulation can be substantially different from that in a rate-deregulated environment, two theoretical models of insurance firms’ decisions are developed. Each incorporates the most important characteristics of the competitive process of a regime. Three levels of decisions (reinsurance, capacity and prices) are treated in a theoretically consistent way to generate econometrically tractable models.

The first model is intended to describe the competitive process between firms in periods of rate regulation. Regulation of rates varies in its form across countries. The most extreme version is the administrative determination of prices. More usual regulation is the regime of prior approval. In the later case, due to regulatory lags and associated costs, insurance rates in regulated markets change very slowly. The model has administratively fixed prices and two stages. The first stage is characterized by reinsurance choices. Capacities are chosen in the second stage. The endogenous choice of the regulated price, either by the regulator or by the firm (subject to prior approval of the regulator), can be modelled in both cases as a previous stage to reinsurance decisions. Since inclusion of this stage does not add substantial insights to the empirical model, it is not developed here.

The second model describes firms’ behavior in the context of deregulated prices. It has three stages. In the first stage, insurance companies decide on reinsurance. Next, capacities are chosen and finally firms decide on prices. In both games the equilibrium is found by backward induction.

Maximum likelihood estimates for the first-order conditions on the optimal choice of capacity are computed to assess the nature of firms’ conduct. The regulated price model is estimated with panel data on twenty-seven firms for the 1982-88 period and the unregulated price model with panel data on thirty-four firms for 1989-90.

The paper is organized in the following way. In the next section, some information on the Portuguese insurance market is presented to motivate the analysis and some of the assumptions made. Several assumptions are tailor-made to the Portuguese auto-insurance market and can be readily adapted to other institutional settings. It sets the historical background for the empirical analysis. The third section briefly presents the first stage of the game (reins-
surance decisions), common to both models. The forth section presents the second-stage game for the regulated price model and lays the foundations for its econometric analysis. The following section, the fifth, presents results for the 1982-88 period, when price regulation was effective. Section six develops the second (and third) stage of the game under price deregulation. Econometric implications are presented. Section seven reports empirical findings for the period 1989-90, after rate liberalization. The regulated-price model is also confronted with the 1989-90 period data. Finally, section eight concludes the paper. Appendices describing the data and econometric procedures follow.

2 Historical Evolution of the Portuguese Insurance Market

Through the seventies and the eighties the Portuguese insurance market experienced profound changes. In 1975, in the aftermath of the April 74 Revolution, nationalization of Portuguese-owned capital occurred.

They became state-owned enterprises. Participations of foreign capital, on the other hand, were not affected. Entry in the market was legally blocked in 1977. Another major change in market structure happened when most state-owned direct insurers were merged into six firms in 1986. Those firms have a considerable size and account for more than half of the market.

Government intervention was not restricted to changes in market structure. Rates were heavily regulated, and the responsibility of price determination was delegated to the national regulatory agency. Even after price deregulation, effective in 1989, a minimum bound on rates was provided by the regulatory agency.

Legal barriers to entry were removed in 1984 and Portuguese accession to the EC in 1986 was another major step towards liberalization. Adjustments of national law to EC requirements were readily made. More recently, in late 1988, prices were liberalized to a considerable extent. Currently, the government is promoting a privatization program for state-owned firms.

Liberalization has been achieved in both entry conditions and market rules. It has produced a strong entry trend in the recent past and that also may have caused a change in firms' conduct. Market structure evolution has been pro-competitive, but too much competition

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*This section is intended to give a brief background on the Portuguese insurance market. For a more detailed exposition, see Silva (1988).*
may become harmful to consumers since they pay first and receive the service later. Senior officers in the Portuguese insurance industry have expressed the concern that the latter scenario characterizes current market competition. The need for an empirical evaluation of the problem is thus warranted.

The analysis is restricted to the auto-insurance market. The main advantage of this procedure is not to have to interpret price behavior for heterogeneous quality products. The loss in generality of the analysis is the cost to bear. It can be argued that even in auto-insurance, different types of insurance contracts can be offered and the issue of “quality” can be raised. Yet, contract conditions were regulated for the whole period and do not differ across firms. The hypothesis of homogeneous products is not an unreasonable one to characterize this line of insurance.

To allow for differences in behavior across firms, three strategic groups of firms are defined according to market shares. The same pattern of market shares distribution has prevailed through the years and a clear identification of groups of firms is possible (although it remains arbitrary in nature). A first group has market shares greater than 5%. A second threshold occurs around 1% of market share. Firms within this interval constitute a postulated second strategic group. The third one includes all firms with market shares less than 1%. So, three strategic classes can be formed in a natural way: big, medium and small firms.\(^5\)

3 The First Stage: Reinsurance Decisions

Insurance firms choose the reinsurance level in a first stage. Although we do not try to get an econometric estimate of reinsurance demand, an explanation of how and why positive reinsurance levels may appear is presented.

Several reasonings have been advanced in the literature to justify the existence of reinsurance. Following Borch (1962) insufficient diversification and risk aversion of direct insurers motivates the existence of reinsurance.\(^5\) It is also assumed that reinsurers are not able to underwrite insurance contracts directly with consumers.

\(^5\)For all years in the sample, the relative size distribution of firms has remained constant in the sense that the composition of postulated strategic groups has not changed. It does not mean that within the group firms remain in the same relative positions. Other criteria to define the strategic groups would be specialization in this line of insurance and geographic dispersion. The first criterion does not discriminate since firms are somewhat homogenous in that respect. The second criterion leads to the same strategic groups.

\(^5\)Other possible justifications for reinsurance can be found in Blazenko (1985), Eden and Kahan (1991) and Borch (1985). For a general introduction to the theme see Carter (1979). In the Portuguese auto-insurance market, reinsurance transactions seem not very important except for two firms. Besides it is usual for Portuguese firms to deal with international reinsurers.
Reinsurance can take a variety of forms. One such form is the excess-of-loss reinsurance treaty: the reinsurer will cover any losses, per contract, more than a pre-defined limit, $D_t$, chosen by direct insurers. It establishes the relevant variables for all contracts reinsured in a fixed period, usually a year.\(^7\)

Reinsurance implies the payment of a premium to the reinsurer, assumed to be a proportion $\rho_t(D_t)$ of total direct premiums. The associated commission is denoted by $z_t(\rho_t)$. This commission depends on firms' bargaining power and is considered to be a fixed percentage of the total volume of premiums reinsured for each firm.

The reinsurer has a well-diversified portfolio and is risk neutral. Competition between reinsurers implies zero expected profits, which means reinsurance premiums are set at actuarially fair prices plus some administrative cost (increasing in the level of reinsurance and convex) of reinsurance firms.\(^8\) Insurance firms have a utility function over wealth, $U(\cdot)$, with non-satiation and constant absolute risk aversion and the axioms of Von Neumann – Morgenstern hold. Firm $i$ faces the problem of maximizing expected utility in the level of reinsurance, $D_t$.

In the resolution of the problem the certainty equivalent is used.\(^9\) Making use of the fact that policies are independently distributed random variables, the objective function of the direct insurer can be written as

$$V_i = E(W_i + \bar{H}_i) - \frac{1}{2} \lambda_i k_i(D_i) \sigma^2_{\text{in}}(D_i)$$  

(1)

where $\lambda_i$ is the degree of (local) risk aversion, $k_i$ is the number of policyholders of firm $i$ and $\sigma^2_{\text{in}}$ denotes variance of profits.\(^{10}\) This expression is an approximation. It holds exactly if profits are a random variable with a normal distribution.

From equation (1) is possible to see an important implication of reinsurance on the next stage equilibria, and its econometric implementation. Marginal cost is defined as the increase in operation costs needed to sell an additional policy. Traditionally, empirical work includes the cost of underwriting the policy and the cost of claims settling. The above expression implies that it should also include the "risk premium" of insurance companies if reinsurance

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\(^7\)Only that form of reinsurance will be investigated. It is conjectured that nothing essential hinges on this assumption and the main conclusions will carry through under other forms of reinsurance. The excess-of-loss reinsurance is chosen because it constitutes the main type of reinsurance in the Portuguese market.

\(^8\)As an alternative interpretation, one could assume some profit requirement by reinsurers, increasing in the level of reinsurance for each particular contract.

\(^9\)An alternative would be to use an explicit utility function. An example is $U(\Pi) = E(\Pi) - \lambda \sqrt{\sigma^2(\Pi)}$. Any specification of a utility function must allow for analytical tractability and its choice is arbitrary.

\(^{10}\)See Pratt (1964: 85-86).
is to be explained by direct insurers' risk aversion. Marginal cost defined in this way is clearly non-observable and its estimation is required.

4 Second Stage: I. The Regulated Price Model

This section considers the second-stage decisions faced by an insurance firm in a context of administratively fixed prices. No analysis of regulation in insurance and of its costs will be made here.\footnote{On the issue and its implications see, for example, van den Berghe (1990), Finsinger and Pauly (1986), Finsinger and Schmid (1991) and Harrington (1987), among others.} Since prices are regulated, insurance companies can only choose reinsurance and capacity variables. First, the firm has to decide the reinsurance policy. In the second stage establishes its capacity.

Insurance firms earn premiums and invest a proportion of that premium income, corresponding to technical reserves that must be held against future (expected) liabilities, receiving some rate of return, \( r_i \), on those investments. The investment strategy is also a decision of insurance firms. Since our interest is not on those decisions, firms are assumed to invest the expected value of claims of each contract following some portfolio strategy previously defined.

The only uncertainty in the model is introduced through claims. They are realized afterwards and are unknown when the contract is made. Only its distribution is known to firms. Firms charge a (fixed) margin over expected claim value, \( E_x_i \), per unit of expected claim. One plus this margin is our notion of price.

Insurance markets are likely to have adverse selection problems. In the market under consideration, companies offered only price contracts.\footnote{With some discrimination according to age (individuals under 25) and years of driving license (under two years).} No price-quantity contracts existed to screen consumers. Differences in risk of consumers, due to adverse selection or other reasons, imply different expected claims per contract for each insurance firm, which is allowed by the model. It is only required that risk composition of consumers remains stable over time. That is, \( E_x_i \) varies across firms but not across time.

Total demand of contracts is given by \( Q(\overline{p}, Y) \), where \( \overline{p} \) is the price, fixed administratively and \( Y \) is a vector of other demand shifting variables. Total capacity in the industry can exceed total demand at the fixed price and some rule is needed to allocate total market demand in an appropriate fashion. There are two reasons by which excess demand is ruled out, one institutional and the other an equilibrium property of the model.
An important feature of the regulatory regime in place was the enforcement power held by the regulatory body. It could make companies underwrite insurance contracts even if they have previously rejected them. Total capacity could not be lower than total demand, otherwise the regulatory agency would have distributed the excess demand across firms. No systematic intervention of this kind has occurred. Additionally, under the assumptions of the model, an insurance firm operating in the market has always an incentive to increase its capacity in the non-cooperative equilibrium.

The most natural assumption to ration consumers between firms is to allocate consumers between firms according to the share of each firm in total capacity. This rule can be justified in the following way. Capacity is defined as the total number of potential consumers that a firm expects to contact. From them only a fraction is transformed into insurance contracts. Firms hire workers or contract with brokers to reach consumers. Suppose that agents (workers or brokers or both) have identical characteristics, independent of the firm with which they are associated. Each agent can contact a proportion \( \phi \) of the total number of consumers willing to buy insurance at the regulated price. Thus, each consumer is reached by \( \phi K \) agents, where \( K \) is the total number of agents in the market. Since prices are fixed, consumers choose randomly between agents. Thus, a particular agent expects to have \( Q(\bar{y})/K \) contracts. If firm \( i \) has \( k_i \) agents, total expected number of contracts of this firm is \( Q(\bar{y})k_i/K \).\(^{13}\)

Firms' real resources technology of making a contract is of the Gorman type:

\[
C_{it}(q_i; w_t) = c_t(w_t)q_i + F_t(w_t)
\]

where \( q_i \) is the number of policies sold and the marginal cost \( c_t \) is considered as a function of inputs prices, \( w_t \). Unlike most studies devoted to the insurance market, the question of existence of scale and/or scope economies is not addressed. It should, nevertheless, be mentioned that results on the topic are far from being conclusive, despite the use of sophisticated econometric techniques.\(^{14}\) Moreover, empirical findings give little support to the hypothesis of significant economies of scale in insurance. At least, they give the same support to the hypothesis of no scale/ scope economies. Non-competitive behavior of firms in the product market is usually disregarded or introduced in an ad hoc way. Since the focus of the present
\(^{13}\)The reasoning underlying the approach is similar to the one in Rogerson's (1982) model of rent-seeking activities.
work is mainly on non-competitive behavior a simple cost structure is assumed. Decreasing average costs are allowed for through the introduction of a fixed cost.

Denote by $C_w(k_{it})$ pure capacity cost function (assumed to be equal across firms). The firm also pays commissions to agents, a percentage $\alpha_i$ of premiums.

Taking all elements together, the expected profit of firm $i$ in period $t$ is defined by:

$$\Pi_{it} = \frac{k_{it}}{\sum_j k_{jt}} Q(\bar{p}_i)\left[\bar{p}_iE_{xi}(1 - \rho_i + z_i) + r_i(1 - \rho_i)Ex_i - Ex_i + \int_{D_i}^{\infty} (x_i - D_i)f(x_i)dx_i - c_i\right] - C_w(k_{it}) - F_{it}$$

with $c_i = \bar{c}_i + \frac{1}{2}x^2i\sigma^2_i(D_i)$. The only substantive difference to usual profit definitions with reinsurance values netted out is on the marginal cost component. The marginal cost to be estimated has both the real resources marginal cost and the "risk cost" of adding an extra contract to the firm’s portfolio.

The first-order condition of firm’s problem is (defining $K_t = \sum_j k_{jt}$ and assuming constant returns to scale in the capacity cost function, $C_w(k_{it}) = \omega_t k_{it}$):

$$\frac{\partial \Pi_{it}}{\partial k_{it}} = \left(\frac{Q(\bar{p}_i)}{K_t} - \frac{Q(\bar{p}_i)}{K_t^2}k_{it}\theta_i\right)\left[\bar{p}_iE_{xi}(1 - \rho_i + z_i - \alpha_i) - Ex_i + \int_{0}^{\infty} (x_i - D_i)f(x_i)dx_i + r_i(1 - \rho_i)Ex_i - c_i\right] - \omega_t = 0$$

where $\theta_i$ summarizes the firm’s conduct.

This is a convenient way of nesting different oligopoly models into an envelope relationship (see Bresnahan 1989). For different values of $\theta_i$, the first-order conditions corresponding to distinct oligopoly models are replicated.

Nash-Cournot behavior means that each firm takes the capacity of others as given: $\theta_i = 1$. The analog to perfect competition is for firms to take total capacity in the market as fixed. The value $\theta_i = 0$ characterizes this behavior.

The other polar case is that of monopoly or total tacit collusion. Collusion must be viewed in coordination terms. Under constant returns to scale firms tend to have capacities in excess of total quantity demanded at the fixed price and demand is rationed according to each firm’s share of total capacity. Profit of firm $i$ is given, in shorter notation, by

$$\Pi_{it} = \varepsilon_{it}Q(p_{it} - h_{it} - c_i)\omega_t k_{it}$$
where $s_{it} = k_{it}/\sum_j k_{jt}$, $p_{it} = \bar{p}_t E x_i(1 - \rho_i + z_i - \alpha_i)$, and $h_{it} = -r_i(1 - \rho_i)E x_i - E x_i + \int_{D_i}^\infty (x_i - D_i) f(x_i) dx_i$. An equiproportional decrease in all $k_{it}$ leaves market shares unchanged and gives higher profits to all firms. Total coordination can be achieved through proportional reduction in all firms' capacities until $K_i = Q_t$ and $d\Pi_i = -\omega_i dK_i$. This is brought up in the first-order condition for profit maximization if $\theta_{it} = 1/s_{it}$. Total coordination is therefore also nested in our formulation.

The assumption of a constant returns to scale technology in the capacity cost function, in addition to constant marginal cost in the real resources cost function of underwriting a contract, has two advantages, besides econometric simplicity: it avoids the need to measure each firm's capacity and allows for independence of equilibrium values of market shares from demand, time specific, shocks.

Equal constant marginal costs and homogeneous product do not imply equal conjectural variations in equilibrium as in the standard oligopoly models (cf. Appelbaum (1982) for example). Reinsurance decisions make the relevant price to be (potentially, at least) different from firm to firm. This feature, not usual in the literature, is specific to the insurance market and stems from the fact that first-period decisions on reinsurance changes the "effective" price faced by the firm.

5 Results for the Regulated-Price Model (1982-88)

The equation to be estimated is the first-order condition for the optimal choice of capacity. Using the compact notation defined above

$$\left[1 - s_{it}\theta_i\right](p_{it} - h_{it} - \omega_i) - b_i = \eta_i + s_{it}, \ b_i = \omega_i K_i / Q_t \quad (5)$$

The equilibrium properties of the model imply that $b_i$ does not respond to demand or capacity random shocks, though $K_i, \omega_i$ and $Q_t$ may differ in time. Capacity costs are assumed to be equal across firms in each period $t$, since contact-making with consumers is mainly a labor intensive activity, and wages are somewhat coordinated across firms, even if in a tacit way.\textsuperscript{15}

Nash-Cournot behavior and "competitive" behavior can be tested on the parameter $\theta$. In contrast, the perfectly collusive outcome implies a different conduct parameter for each firm.\textsuperscript{16}

\textsuperscript{15}The empirical evidence on wage differences between firms is scarce - only the average wage per firm can be computed - but its standard deviation does give some support to this assumption. Additionally, the Portuguese Insurers Association (APS) does some coordination in wage policies between firms.
in each period.

Due to data limitations, there is no possibility of treating both $\theta_i$ and $c_i$ as different from firm to firm (fixed effects). To simplify matters, both $c_i$ and $\theta_i$ can have only three values, allowing differentiation between postulated strategic groups of firms. Group coefficients are defined by:

$$\theta_i = \begin{cases} 
\theta_1 & \text{if } i \not\in (D6 \cup D7) \\
\theta_1 + \theta_2 & \text{if } i \in D7 \\
\theta_1 + \theta_3 & \text{if } i \in D6 
\end{cases}$$

$$c_i = \begin{cases} 
c_1 & \text{if } i \not\in (D6 \cup D7) \\
c_1 + c_2 & \text{if } i \in D7 \\
c_1 + c_3 & \text{if } i \in D6 
\end{cases}$$

with sets $D6$ for big firms, and $D7$ for medium firms, defined as $D6 = \{i : s_i \geq 5\%\}$ and $D7 = \{i : 1\% < s_i < 5\%\}$.

Parameters $c_2$ and $c_3$, $\theta_2$ and $\theta_3$ are "group" deviations to the basic coefficients, and should be interpreted accordingly. Zero values do not mean that firms are equal. A firm-specific random effect ($\nu_i$) is introduced and it can be interpreted as individual departures from the marginal cost basic parameter (although other firm-specific effects besides marginal cost can be present in it).

Alternative, nested, models of oligopolistic interaction are included in the general form given in equation (5). Maximum likelihood estimates are presented in Table 1.\textsuperscript{16}

Estimates are qualitatively robust to the maintained specification. The broad features are: 1. market conduct parameters are always statistically significant and different across strategic groups of firms; 2. marginal cost parameters also reveal a consistent pattern across specifications but the marginal cost parameter, $c_2$, seems not significantly different from zero in the more general model; and 3. time effects appear to be statistically not different from zero (the adjusted Wald test statistic has a value of 13.89 with 7 degrees of freedom; the critical value at the 5% level of significance is 14.067).

Non-significance of time effects is not surprising despite that several industrial organization empirical studies have found pro-cyclical movements in price-cost margins.\textsuperscript{17} The model developed has the property that equilibrium values adjust to cyclical shocks on demand such that the coefficient to be estimated is independent of time-specific shocks. The insignificance of the reference marginal cost of capacity parameter, $b_1$, suggests that this may be an effect intrinsic to the firm. In that case, the effect is captured by the firm-specific random effect.

\textsuperscript{16}Estimated values of the firm-specific random effects are omitted for simplicity. They can be easily calculated by straightforward adaptation of the formulae proposed by Taub (1979). The crucial characteristic to the prediction of the random effect is its additive nature.

\textsuperscript{17}See Bils (1987), Machin and van Reenen (1993) and the references therein.
Table 1: Main Results

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<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<td>(2.34)</td>
<td>(2.30)</td>
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Note: the values between brackets are absolute t-statistics based on the adjusted standard deviations of White (1982).
Table 2: Conduct parameters (model D)

<table>
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<tr>
<th>Group</th>
<th>$v_i$</th>
<th>$(1 - \bar{s}_i)/\bar{s}_i$</th>
<th>$\bar{v}_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>big firms</td>
<td>7.3</td>
<td>7.034</td>
<td>1.04</td>
</tr>
<tr>
<td>medium firms</td>
<td>31.5</td>
<td>36.110</td>
<td>0.87</td>
</tr>
<tr>
<td>small firms</td>
<td>178.6</td>
<td>230.62</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Table 3: Wald tests for collusive behavior (model D)

<table>
<thead>
<tr>
<th>Test</th>
<th>d.f.</th>
<th>$W$ statistic</th>
<th>$\chi^2_{(4, F)}$</th>
<th>Accept/Reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_{small} = 1$</td>
<td>1</td>
<td>19.15</td>
<td>3.84</td>
<td>R</td>
</tr>
<tr>
<td>$v_{medium} = 1$</td>
<td>1</td>
<td>2.98</td>
<td>3.84</td>
<td>A</td>
</tr>
<tr>
<td>$v_{big} = 1$</td>
<td>1</td>
<td>4.71</td>
<td>3.84</td>
<td>R</td>
</tr>
<tr>
<td>$v_i = 1, \forall i$</td>
<td>3</td>
<td>26.61</td>
<td>7.81</td>
<td>R</td>
</tr>
</tbody>
</table>

On the characterization of cost structures, the estimates indicate that marginal costs have differed across groups of firms. Lower marginal costs for the groups of big and medium firms are identified, with no distinction in marginal costs between those two groups. The result does not mean that small firms are inefficient when compared to other firms. Different technology choices can justify the pattern. Small firms may have chosen a technology with low fixed costs and high marginal costs. If big and medium firms chose a technology with low marginal costs, having in turn higher fixed costs the ordering of marginal costs is consistent with empirical findings but nothing can be said about relative efficiency of firms.

Different conduct parameters across strategic groups of firms are identified.18

Estimated coefficients are quite high for all strategic groups and well above the threshold value of Nash-Cournot equilibrium. Wald tests reveal, for the three strategic groups of firms, a more collusive behavior than Nash-Cournot.

The values of the conduct parameter across strategic groups exhibit a pattern consistent with coordination between firms to reduce capacity while keeping market shares roughly constant.

To evaluate the collusive outcome, conduct parameter estimates should be adjusted by a relative market share ratio. Collusive outcomes can be characterized by $\theta_{it} = 1 + v_i(1 - s_{it})/s_{it}$. Values for $v_i$ in the interval [0,1] indicate a more collusive behavior than the Cournot equilibrium ($v_i = 0$) but less than full collusion ($v_i = 1$). The calculated value of $v_i$ for each strategic group of firms is presented in Table 2.19

---

18Equal market behavior between any two (or three) strategic sets of firms is rejected.

19It is computed as the estimated conduct parameter (minus one) divided by $(1 - \bar{s}_i)/\bar{s}_i$ for each group, where $\bar{s}_i$ is the average market share within the strategic group across firms and time.
Wald tests for collusive behavior are presented in Table 3.\textsuperscript{20}

A fully coordinated outcome, achieved by equiproportional reductions in capacity by all firms in the market, is not supported by the data. Small firms had a market conduct more competitive than full collusion. On the other hand, perfect coordination cannot be excluded as a description of market interaction for the big and medium firms.

One particular result calls for further explanation: in the restricted model, the parameter of market behavior for big firms exceeds one. A possible rationalization for this value is that it results from some tacit coordination game, where deviations to the agreement are restrained by implicit punishments. To sustain this kind of agreement it may be necessary that an increase in one firms' capacity triggers a more than proportional reaction by other firms.

Total coordination means that firms agree on some total capacity reduction, $dK$, which must be fully distributed among all firms. By definition of $\theta_i$ as $dK/dk_i$, it is straightforward to establish that

$$\sum_i \frac{1}{\theta_i} = 1 \quad (6)$$

Thus, total coordination yields a testable restriction on estimated conduct parameters.\textsuperscript{21} A coordinated outcome may entail less than proportional capacity reductions by some firms if compensated by more than proportional contractions by other firms. The values for $\nu_i > 1$ for big firms and $\nu_i < 1$ for small firms suggests that can be the case. The Wald test for condition 6 has yielded a value of 0.51, which does not reject the null hypothesis of a coordinated outcome.\textsuperscript{22}

The coordination process seems to have been characterized by a less than proportional capacity reduction by small firms, compensated by a more than proportional contraction by big firms, with the group of medium firms adhering strictly to equiproportional changes in capacity. Small (big) firms have higher (lower) market shares than the ones that would prevail in a Nash equilibrium.

Differences in marginal costs may have been a partial justification for differences in market shares. However, they do not tell the whole story. Tacit coordination to keep total capacity low through reductions in each firm's capacity seems to fit the data well. Additional explanations for differences in market shares must be found prior to the estimation period. How and

\textsuperscript{20}Note that inferences on the estimated parameters are conditional on the vector of market shares.

\textsuperscript{21}Equiproportional capacity reductions are a particular case of this condition in the sense that $\nu_i = 1$ implies $\theta_i = 1/s_i$ and the sum of all market shares equals necessarily one.

\textsuperscript{22}The critical value for the 5\% level of significance of the $\chi^2$ distribution with one degree of freedom is 3.84.
why that coordination was made possible is not explained by the model. The econometric
evidence does not contradict the idea that market structure and equilibrium in the Portuguese
insurance industry have been shaped by government decisions, with little economic rationale
behind them.

A possible “leader-follower” story is also inconsistent with the results. Such a story comes
naturally to mind since big firms were all state-owned in the period and some “government-
induced” coordination may have prevailed among them, with other, much smaller, firms
behaving as followers. Being a follower means, in the context of the model, taking aggregate
capacity as given. As described, Nash-Cournot conduct was rejected in favor of more collusion,
thus rejecting the “follower” behavior for small firms. It does not imply that “government-
induced” coordination did not exist. It points out that smaller firms have participated in
it.

Overall, market conduct, as perceived by the model, has been quite collusive in the period
under review.

6 Second Stage: II. The Unregulated-Price Model

Pricing freedom constitutes the main modelling difference from the previous model. To des-
crIBE firms’ decisions, a three-stage game is considered. In the first stage, insurance companies
decide upon reinsurance policies. Next, capacities are set. Capacity again has the meaning of
potential contacts. In the third stage, firms compete in prices, given the established capacities
and reinsurance policies. Firms can produce contracts, at some marginal cost, until capacity
is reached.

To deal with price competition, a formulation in the spirit of the work of Levitan and
is considered. They have shown that if capacities are chosen simultaneously and then firms
engage in price competition, the set of equilibrium capacities coincides with the Cournot
quantities. If each firm has limited capacity and demand is continuous and decreasing, in
general, there is only one equilibrium.\textsuperscript{23} The result depends on the demand rationing as-
sumption employed: low-priced firm serves the consumers with the highest reservation prices.
Despite criticisms such assumption is maintained here. The result says that the one-shot
game in capacity mimics the equilibrium of a two-stage game with capacity choice in the first

\textsuperscript{23}A proof can be found in Kreps and Scheinkman (1983), Osborne and Pitchik (1986) and Herk (1993).

15
period and price competition in the second period. Also, Herk (1993) shows that in markets with switching costs, the Cournot behavior is the equilibrium. It suffices, thus, to analyze firms' capacity choices. The underlying economic rationale is that prices adjust more quickly than capacities. Since capacities are associated with the number of total insurance contracts that a firm can make, it is reasonable to assume that prices are decided after firm's choices about capacity (workers, brokers, etc ...).

It is also assumed that capacities are observed by all competitors before prices are chosen. This is not unrealistic due to the particular definition of capacity used. Firms can have a good idea of other firms' policies regarding employment and brokerage.

The problem of firm \( i \) is

\[
\max_{k_{it}} \Pi_{it} = k_{it} \left( p(K) E x_i (1 - \rho_i) + \tau_i (1 - \rho_i) E x_i - E x_i + \int_{D_i} (x_i - D_i) f(x_i) dx_i - c_i - \omega_i \right) - F_i
\]

(7)

where \( p(K) \) denotes the inverse demand function. The first-order condition is given by

\[
\frac{\partial \Pi_{it}}{\partial k_{it}} = p(K) E x_i (1 - \rho_i) + \tau_i (1 - \rho_i) E x_i - E x_i - (c_i + \omega_i) + \int_{D_i} (x_i - D_i) f(x_i) dx_i + k_{it} E x_i (1 - \rho_i) + \frac{\partial \eta}{\partial x} \theta_i = 0
\]

(8)

where \( \theta_i \) is again a conduct parameter. Define \( \varphi = - (\partial K / \partial p)(p/K) \) as the (constant and finite) demand elasticity and rewrite the first-order condition as

\[
p_{it} (1 - s_{it} a_i) = c_i + \omega_i + h_{it}
\]

(9)

where \( a_i = \theta_i / \varphi \).

The model is not fully identified in the sense that it is not possible to calculate exactly the conduct parameter for each firm (or group of firms) unless there is some knowledge of the price demand elasticity, or at least, there is some estimate of it.\(^{25}\)

In the literature several ways of escaping from the problem of identification of the market power parameter have been used. The most common one is to use an estimate for the price demand elasticity borrowed from other studies. An alternative is to estimate an equation for market demand alongside the first-order conditions satisfying certain identification conditions (Bresnahan 1982, Lau 1982).

\(^{24}\) For a discussion on the rationing rule and its equilibrium implications see Herk (1993) and Davidson and Deneckere (1986).

\(^{25}\) Note that \( \omega_i \) cannot be empirically separated from \( c_i \) and it will be omitted throughout. Estimated values for \( c_i \) are, rigorously, for \( c_i + \omega_i \).
Neither of the two options is available. The few econometric studies for the Portuguese insurance market (Portugal 1988, Araújo 1984) do not hold reliable estimates for the demand price elasticity, and given our short period of data, its estimation is not possible. The primary goal of the analysis will be to identify different strategic groups and not the exact exercise of market power they exhibit. In equation (9) the parameter $a_i$ includes both $\theta_i$ and $\varphi$ and it is not possible to disentangle one from the other. However, if for different strategic groups distinct values for $a_i$ hold in the data, then, for the same market demand elasticity, one can say that proposed groups of firms differ in their strategic behavior. In particular, if $a_i/a_j > 1$ then the strategic group with estimated parameter $a_i$ behaves less competitively than the strategic group with parameter $a_j$. Competitive behavior can still be tested since it implies $a_i = 0$.

7 Results for the Unregulated-Price Model (1989-90)

The relationship (9) encompasses the various alternative versions for the flexible-price model. The most general model in our framework has three distinct (marginal) cost structures and three different strategic groups of firms (previous definitions hold).

The parameter $\omega_2$ accounts for the existence of time effects. A random effect specific to the firm, $\eta_i$, captures unobservable firm-specific characteristics that may affect its behavior. The (pseudo) maximum likelihood estimates are displayed in Table 4.

The estimated parameters are robust across specifications. The coefficients $c_1$ (marginal cost) and $\omega_2$ (time effect) are statistically significant at the 5% significance level and show similar values in all models. Omission of differentiation coefficients between strategic groups both in marginal cost and behavior parameters does not introduce substantial changes in the estimates. Those results constrain strongly with the previous period.

Two explanations for the dissipation of differences in marginal cost across groups of firms can be offered: the sample of firms was expanded to include entry of new firms after entry deregulation. The new firms were typically in the strategic group of small firms. If they have lower marginal costs than incumbent firms in the group, differences at the group level to big and medium firms can be attenuated. This effect does not require any change in the marginal cost of existing firms. The marginal cost differential is now captured by the firm-specific random effect. The other explanation is that cost structures have evolved through time in a smooth way, and the shift is only detected in the more recent period.
Table 4: Estimated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>-8.977</td>
<td>-2.686</td>
</tr>
<tr>
<td></td>
<td>(0.34)</td>
<td>(3.44)</td>
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<tr>
<td>$a_2$</td>
<td>7.130</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td></td>
</tr>
<tr>
<td>$a_3$</td>
<td>6.748</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td></td>
</tr>
<tr>
<td>$c_1$</td>
<td>3.563</td>
<td>3.056</td>
</tr>
<tr>
<td></td>
<td>(3.95)</td>
<td>(5.71)</td>
</tr>
<tr>
<td>$c_2$</td>
<td>-1.953</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.73)</td>
<td></td>
</tr>
<tr>
<td>$c_3$</td>
<td>-0.627</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.34)</td>
<td></td>
</tr>
<tr>
<td>$\omega_2$</td>
<td>1.991</td>
<td>1.956</td>
</tr>
<tr>
<td></td>
<td>(2.95)</td>
<td>(4.88)</td>
</tr>
<tr>
<td>$\sigma_r^2$</td>
<td>3.509</td>
<td>4.200</td>
</tr>
<tr>
<td></td>
<td>(1.83)</td>
<td>(1.83)</td>
</tr>
</tbody>
</table>

Note: values between brackets are the absolute t-statistic based on the adjusted standard deviations of White (1982).

The negative sign for the basic conduct parameter ($a_1$), though not significantly different from zero in the general model, is also a problematic result. It lacks theoretical interpretation and implies that the second-order condition for profit maximization may not hold.\(^{26}\) Since a zero value means a competitive outcome, a value lower than zero can be termed "supercompetitive." Under this interpretation, firms have behaved more aggressively than predicted by perfectly competitive behavior.

The result can be based on firms' miscalculations about expected claims. A natural way for such miscalculations to occur is to have a recursive way of estimating expected claims. In a context of rising repairing costs or increasing accidents rate, underestimation of expected claims will occur and "right" decisions of firms ex-ante will appear as non-optimal ex-post. Econometric estimates will be biased, and the bias is likely to produce an estimate for the conduct parameter lower than its true value. For example, taking $\hat{h}_{it} = 0.75h_{it}$ (to account for the underestimation of expected claims) has yielded a non-significant estimate for $a_2$. Of course, the value 0.75 is arbitrary and has only illustrative purposes. Underestimation of expected claims means that perceived marginal profit is higher than its actual value and too much capacity is deployed by firms. As a result, a more than "desired by firms" competitive

\(^{26}\)Demand must be sufficiently concave to satisfy second-order conditions. For local changes in demand, that is, when a linear demand function is a good approximation, $a_i < 0$ implies definition of a minimum.
interaction is measured. A full adjustment for this problem must trace back to first-stage decisions on reinsurance. Not only assumptions on how expectations of future claims are formed must be made, but also hypotheses about changes in optimal reinsurance decisions must be introduced. Since any possible adjustment has an arbitrary nature, a full investigation of this issue is beyond the scope of this work and it is not pursued here.

Alternatively, inertia of firms' decisions and outside pressures that may have had the effect of preventing the full implications of price deregulation. It is common belief that price adjustments in the Portuguese auto-insurance market have not been fully determined by market forces. Casual empiricism suggests that an implicit ceiling on price (premium) increases may have existed on some firms as a result of government pressure. The strategic group of big firms was constituted by state-owned firms and government policy was directed towards lowering inflation in the period under review. On the other hand, a lower bound on rates was set by the regulatory agency. Under such circumstances, the regulated price model may be a better description of market interaction than the unregulated one.

The following econometric expression includes the first-order condition on the optimal capacity choice of both models as particular cases:

\[ p_a (1 - s_t a_t) - h_t - c_t - b_t + \xi a_t s_t (h_t + c_t) = 0 \]  \hspace{1cm} (10)

where \( \xi = 0 \) gives the empirical specification for the unregulated price model, while \( \xi = 1 \) gives the empirical model for the regulated price case. A natural way to test one model against the other is to test \( \xi = 0 \) and \( \xi = 1 \). But, the test may be inconclusive. If both null hypotheses are rejected or both are not rejected, no selection is made. It is important to stress that coefficients have a different meaning in each case since models have distinct assumptions about market rules. Values for \( \xi \) other than zero or one have no interpretation. The testing procedure is, in the present case, just a pure econometric artifact.

Equation (10) is estimated for model B under the maintained hypotheses \( \xi = 1, \xi = 0 \) and no restriction on \( \xi \). No definite answers are obtained. Both null hypotheses are rejected, independently of the model specification: the Wald test statistics for \( \varepsilon = 0 \) and \( \varepsilon = 1 \) are, respectively, 74.22 and 32.24, well above of the critical value of \( \chi^2_{(1)} \) at the 5% level of significance, 3.84.

Despite this indeterminacy there are no fundamental changes in the qualitative results. The competitive nature of the estimated market equilibrium is robust to the choice of the
Although "destructive competition" arguments may be used by firms to justify cartel behavior, this seems not to be the case. Moreover, implicit ceilings may have prevented firms from adjusting their variables in an optimal manner (from their point of view). Accounting for it through estimation of the fixed price model also reveals a competitive interaction in capacity choices. Another explanation for the results is miscalculation of expected claims. Anyhow, a competitive outcome seems to characterize the market in the years 1989-90.

8 Final Remarks

A methodology using econometric estimation of firms' first-order condition for profit maximization in "capacity" choice to assess the degree of market power in homogeneous insurance lines was proposed.

Since price liberalization is a fundamental change in market rules, two models are constructed to account for the different interaction mechanisms that may prevail before and after price liberalization. Firms are assumed to have three levels of decisions in a price deregulated environment and two levels of decisions under price regulation (the prior stage of price setting is omitted). This leads naturally to the specification of three-stage and two-stage games, respectively.

In the first stage of both models, firms choose reinsurance policies. In the second stage firms choose "capacities." Capacity has the meaning of ability of firms to reach consumers. The typical decision to capture in this stage is the choice of the number of branch offices, agents, brokers and the like. Under price regulation the model ends at this point. All firms face the same regulated price. Endogenous determination of the regulated price would amount to introduce an additional stage before reinsurance decisions.

In a framework where firms have price setting ability, there is a third stage, characterized by price competition. In such model, the result of Kreps and Scheinkman (1983), Osborne and Pitchik (1986) and Herk (1983) is used to specify decisions in capacities only. Both games are solved by backward induction.

The first stage of the game justifies why and under which circumstances a positive level of reinsurance should be expected. It also gives a sound justification for the usual practice of netting out reinsurance values from direct insurance values. Another important implication of the reinsurance block is in the definition of marginal costs. A risk premium component
should be included if firms are risk-averse. In the models proposed, firms' risk aversion is a necessary condition for the existence of reinsurance and reinsurance is observed in practice even if at low levels.

Starting from definitions of objective functions, cost functions and market demand conditions, the optimal choice of capacities in the second stage is determined by a first-order condition, which can be estimated to evaluate market conduct of insurance firms.

An application to the Portuguese auto-insurance market is presented. Two distinct time periods are considered and panel data is used. The two periods are 1982-88, characterized by price regulation, and 1989-90, characterized by price liberalization.

Data limitations and their quality motivates an econometric modelling with very simple demand and cost specifications. An additive random component error term is considered, to account for the presence of other firm-specific effects that may influence optimal choices which are not explicitly accounted for in the model. Firms are divided into three strategic groups according to their relative size. Strategic groups' differences in marginal cost structure and market conduct are investigated.

Two simplifications are noteworthy: the approximation by the certainty equivalent to the expected utility of direct insurers and the functional form for the cost function. Those simplifications are chosen for empirical tractability. More complex specifications would increase the number of parameters to be estimated, with negative effects upon the quality of estimates. To simultaneously estimate a cost function would be too much to ask from available data.

Econometric results suggest that for the latter period (1989-90), even if no clearcut distinction between the regulated and the unregulated price model has emerged, firms behaved competitively in the market. The competitive nature of the market outcome cannot be attributed to the particular model employed. This contrasts heavily with empirical results for the previous period (1982-88), where a significant degree of collusion was identified and both hypotheses of competitive and Nash-Cournot behavior in capacities were rejected in favor of a more collusive market outcome. Results are consistent with near perfect coordination among insurance firms.

Apparently, an important change in insurance firms market conduct has occurred. Market behavior of insurance firms has become more aggressive and competitive behavior cannot be rejected. This conclusion is reinforced by the fact that competitive behavior in the latter period is captured by both models.
On the marginal cost structure of firms, econometric results point out that bigger firms have experienced lower marginal costs over the 1982-88 period, but that advantage seems to have disappeared in the latter period. Since marginal cost structures are analyzed with reference to postulated strategic groups of firms, entry by small firms exhibiting low marginal costs as well as adjustments in older firms in the market imposed by competitive pressure may be in the origin of this result.

Note that no inference can be made about average costs and therefore about the existence or not of economies of scale. Inferences on economies of scope are also beyond our possibilities since the analysis was restricted to one particular line of insurance.27

The results are not inconsistent with operating losses, since fixed costs are still not accounted for. In the presence of high fixed costs, heavy losses can characterize a firm’s profit in each year. In the short-run, decisions are based on marginal costs and it is precisely this aspect that has been captured by the analysis. Longer-run adjustments, such as whether there are too many firms in the market, cannot be properly answered within our framework. It can only be said that “competitive outcomes” detected would indeed lead to negative profit values in the presence of fixed costs. Therefore, our results do not contradict the claim that too much competition has characterized the Portuguese insurance market in recent years.

A final comment on market performance is in order. The conclusion to be drawn is that, in the pricing dimension, the performance of the Portuguese auto-insurance market has been satisfactory. Under price regulation, excess capacity serves no purpose from a social point of view. A coordinated outcome yields in this context a higher social welfare than a non-coordinated one.

After deregulation, the competitive outcome empirically observed constitutes also a reasonable market allocation as well. It may be argued that too much competition is in place, if positive fixed costs exist. Distortions due to exercise of market power are not important.

Of course, other dimensions of the insurance service, like speed in settling claims, or the use of inefficient technologies, may not be near the socially desirable allocation. Further improvements in social welfare are not precluded. The focus of future work should be on non-price characteristics of auto-insurance products.

27 The magnitude of estimated marginal costs is of reasonable order when compared to actual average costs (which should be regarded with care since accounting methods underlying their calculation can vary from firm to firm).
A Data set

Published accounts include costs for each type of insurance. Criteria for allocating common costs between different lines of insurance it is not well defined and firms can easily manipulate results per line of business through cost allocation. For example, some of them use premiums to allocate common costs; others use claims and still others make an average of both indicators. There is no guarantee that allocations are made consistently either in a cross-section dimension or in a time-series dimension. Given this, we took the view that allocated costs do not reflect the true marginal costs, and proceeded to estimate marginal cost in the course of action. Moreover, before 1984 not even such cost allocation was published.

As is well known, premiums and claims published in the same annual reports do not correspond to the same economic period. All variables are calculated with reference to premiums charged in a given year.

The data are obtained from published accounts and statistics of the Instituto de Seguros de Portugal, the Portuguese regulatory agency. It covers a period of seven years (1982-88) for the fixed price model and two years (1989-90) for the flexible price model. Panel data on twenty-seven firms is used in the first model. New firms in each of the periods are ignored. For the second period, the data include thirty-four firms. The variables $p_{it}$ and $h_{it}$ are obtained from published data as follows. The variable $p_{it}$ is constructed with premiums of direct insurance minus premiums of ceded reinsurance plus reinsurance commissions minus direct insurance commissions. The variable $h_{it}$ is obtained as direct insurance claims minus reinsurance claims received minus revenues of investments corresponding to technical reserves. All the necessary values can be found in Estatísticas da Actividade Seguradora - Elementos Estatísticos I. The number of policies and accidents of each firm can be found in Estatísticas da Actividade Seguradoras - Elementos Estatísticos II. Both publications are from Instituto de Seguros de Portugal.

Variables defined in averaged values or in current values of claims do not yield qualitatively different results. Only results based on average values for claims are reported, since giving some preference to this procedure is natural (Doherty 1981).

The data set used has excluded new firms that have entered the market during each observation period. Firms that have exited the market were also eliminated from the sample. The

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sample of firms always covers more than 99% of the auto-insurance market, measured either by contracts or by premiums. Statistical information on the data is presented in the following Table. It has information on transformed variables for the regulated and the unregulated price models.

Table: Summary Statistics

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<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>( s_{it} )</td>
<td>3.7</td>
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<td>1.83</td>
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Correlation Matrix (1982-88)

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<th>( D6_{it} )</th>
<th>( D7_{it} )</th>
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<td>( p_{it} - h_{it} )</td>
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<td>( 1 )</td>
<td>( -0.24 )</td>
<td>( 1 )</td>
</tr>
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<td>( D6_{it} )</td>
<td>(-0.02)</td>
<td>( 1 )</td>
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<td></td>
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<td>( D7_{it} )</td>
<td>(-0.32)</td>
<td>( 1 )</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>0.026</td>
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<td>( h_{it} )</td>
<td>6.974</td>
<td>3.671</td>
<td>0.992</td>
<td>18.448</td>
</tr>
</tbody>
</table>

Correlation Matrix (1989-90)

<table>
<thead>
<tr>
<th></th>
<th>( s_{it} )</th>
<th>( p_{it} )</th>
<th>( h_{it} )</th>
<th>( p_{it} - h_{it} )</th>
<th>( D6_{it} )</th>
<th>( D7_{it} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s_{it} )</td>
<td>1</td>
<td>(-0.38)</td>
<td>(-0.33)</td>
<td>(-0.31)</td>
<td>( 0.96 )</td>
<td>( 0.02 )</td>
</tr>
<tr>
<td>( p_{it} )</td>
<td>( 1)</td>
<td>( 0.82)</td>
<td>( 0.47)</td>
<td>( 0.27 )</td>
<td>(-0.23)</td>
<td>(-0.24)</td>
</tr>
<tr>
<td>( h_{it} )</td>
<td>( 0.96)</td>
<td>( -0.23)</td>
<td>( -0.23)</td>
<td>( 0.27)</td>
<td>(-0.23)</td>
<td>(-0.24)</td>
</tr>
<tr>
<td>( p_{it} - h_{it} )</td>
<td>( 0.02)</td>
<td>( -0.24)</td>
<td>( -0.24)</td>
<td>( -0.23)</td>
<td>( 1)</td>
<td>( 1)</td>
</tr>
<tr>
<td>( D6_{it} )</td>
<td>( 0.96)</td>
<td>(-0.23)</td>
<td>(-0.23)</td>
<td>( -0.23)</td>
<td>( 1)</td>
<td></td>
</tr>
<tr>
<td>( D7_{it} )</td>
<td>( 0.02)</td>
<td>(-0.24)</td>
<td>(-0.24)</td>
<td>(-0.24)</td>
<td></td>
<td>( 1)</td>
</tr>
</tbody>
</table>

B Estimation procedures

B.1 Econometric equations to be estimated

An error term \( u_{it} \) is included in the first-order condition of each firm. The econometric specification for the regulated-price model estimated has the (implicit) form:

\[
(p_{it} - h_{it} - a_i)(1 - s_{it} \theta_t) - b_t = u_{it}, \quad i = 1, \ldots, N; t = 1, \ldots, T
\]  

(11)

where \( N \) is the number of firms and \( T \) is the number of time periods. Substituting \( c_i \) and \( \theta_t \) by their definitions and introducing \( D6_{it}, D7_{it} \) and \( D_{jt}, j = 83, \ldots, 88 \) as dummy variables defined by
\[ D_{6i} = \begin{cases} 1 & \text{if } i \in D6 \\ 0 & \text{otherwise} \end{cases} \quad D_{7i} = \begin{cases} 1 & \text{if } i \in D7 \\ 0 & \text{otherwise} \end{cases} \quad D_{ij} = \begin{cases} 1 & \text{if } t = j \\ 0 & \text{otherwise} \end{cases} \]

the redefined implicit equation is

\[
(p_{it} - h_{it} - c_1 - c_2 D_{7i} - c_3 D_{6i})(1 - (a_1 + a_2 D_{7i} + a_3 D_{6i})s_{it}) - b_1 - b_2 D_{83i} - b_3 D_{84i} - b_4 D_{85i} - b_5 D_{86i} - b_6 D_{87i} - b_7 D_{88i} = u_{it}
\]

Similarly, the econometric model for the 1989-90 period is, after substitution of \(a_i\) and \(c_i\) by their definitions (identical with the ones above):

\[
p_{it}(1 - (a_1 + a_2 D_{7i} + a_3 D_{6i})s_{it}) - c_1 - c_2 D_{7i} - c_3 D_{6i} - h_{it} - \omega_1 - \omega_2 D_{90i} = u_{it}
\]

It is easy to see that components \(c_1\) and \(\omega_1\) cannot be empirically separated.

### B.1.1 Random effects

The random term \(u_{it}\) is composed of a pure random component across time and firms, \(\varepsilon_{it}\), and of a random effect specific to each firm, \(\eta_i\). That is,

\[ u_{it} = \eta_i + \varepsilon_{it} \]

The presence of the firm-specific effect \(\eta_i\) introduces correlation between residuals of the same firm in different periods. Residuals from different firms are independent. The random term \(\eta_i\) is assumed to have zero mean and finite variance \(\sigma^2_{\eta_i}\), to be independently distributed across firms and uncorrelated with \(\varepsilon_{it}\) or with any explanatory variable (\(X_{it}\)). On the other hand, \(\varepsilon_{it}\) is a white noise term, with zero expected value, finite variance \(\sigma^2_{\varepsilon}\) and it is uncorrelated through time and with any explanatory variable.\(^{29}\) The random effect \(\eta_i\) captures other influences that are specific to each firm and not explicitly incorporated in the model. Two extreme alternatives are possible in the treatment of \(\eta_i\). On the one hand, one can treat \(\eta_i\) as equal for all \(i\). On the other hand, one can treat \(\eta_i\) as different for each firm \(i\). The procedure of treating \(\eta_i\) as a random variable provides an intermediate solution between those two polar cases. The use of random effects reflects the need of parsimony in model parametrization and it is considered a superior alternative to computation of pooled-data estimates, although

\(^{29}\)See Hsiao (1986).
some gains in efficiency could be gained in the latter case, when the number of observations available in the cross-section dimension is small. The additive nature of the specific effect simplifies the problem of model estimation to a considerable extent.

B.2 Econometric methods

From the definitions of \( \eta_t \) and \( \varepsilon_{it} \), it is straightforward to establish that

\[
E[u_{it}] = 0; \quad E[u_{it}^2] = \sigma^2_\eta + \sigma^2_\varepsilon; \quad E[u_{it}u_{is}] = \sigma^2_\eta, \quad t \neq s, \forall i; \quad E[u_{it}u_{js}] = 0, \quad j \neq i, \forall t, s
\]

So, \( E[U'_iU'_i] = \sigma^2_\varepsilon e_T'e_T + \sigma^2_\eta I_T = V \) where \( U_i \) is the residual vector for each firm \( i \), \( e_T \) is a sum vector of order \( T \times 1 \) and \( I_T \) is an identity matrix of order \( T \times T \).

The error structure assumed implies a variance-covariance matrix typical of error components models. Additionally both models are non-linear. Those characteristics justify estimation by maximum likelihood methods. The (pseudo) log likelihood function for both models, when \( \eta_t \) and \( \varepsilon_{it} \) are assumed to be normally distributed, is given by

\[
\log L = -\frac{NT}{2} \log 2\Pi - \frac{N}{2} \log |V| - \frac{1}{2} U'(I_N \otimes V^{-1})U
\]

(12)

where \( \otimes \) denotes the Kronecker product. The residuals \( U \) are given by \( u_{it} = f(X_{it}, \delta) \) where \( X_{it} \) is the vector of variables for firm \( i \) and period \( t \) and \( \delta \) is the vector of parameters to be estimated. The function \( f \) generically denotes the non-linear implicit form of the model. The expression for \( |V| \) and \( V^{-1} \) are:

\[
|V| = \sigma^2_\varepsilon^{2(T-1)}(\sigma^2_\eta + T\sigma^2_\varepsilon); \quad V^{-1} = \frac{1}{\sigma^2_\varepsilon} \left[ I_T - \frac{\sigma^2_\eta}{\sigma^2_\varepsilon + T\sigma^2_\varepsilon} e_T'e_T \right]
\]

The simultaneous solution of the first-order conditions is, in general, complicated. The log likelihood function can be simplified, for estimation purposes. A matrix \( P \) can be constructed such that transformed residuals are homoscedastic and normally distributed. \( P \) is defined by

\[
P = I_N \otimes \left( I_T - \left( 1 - \frac{\sigma^2_\eta}{\sigma^2_\varepsilon} \right) \frac{1}{T} e_T'e_T \right)\]

where \( \sigma^2_T = \sigma^2_\varepsilon + T\sigma^2_\eta \). The procedure of "cleaning" the residuals by application of a transformation matrix \( P \), a usual trick in error-components models, makes sense despite the non-linear structure of the model. The crucial point to note here is that \( u_{it} \) can be expressed as linear in some redefinition of the original variables and parameters, and maximum likelihood estimation of the implicit form of the model can then be carried out. The ML procedure in the econometric package TSP (version 4.2) for Macintosh

\[\text{See Fuller and Battese (1973: 627) or Judge et al. (1985: 524).}\]
is used to compute maximum likelihood estimates. On the numerical methods and their statistical properties see Berndt et al (1974) and Gallant (1987).

The various models we consider are nested, and standard econometric techniques for model selection are employed. The test statistic used for selection between competing models is the adjusted Wald test proposed by White (1982). The preference given to this statistic over the likelihood ratio test is due to the fact that the adjusted Wald test can be computed in a consistent way even if there is misspecification in the probability distribution of the model.³¹

White (1982) shows that under appropriate assumptions, the adjusted Wald test converges in distribution to a central chi-square distribution with \( J \) degrees of freedom, where \( J \) is the number of restrictions to be tested, when the null hypothesis is true. A brief description of the adjusted Wald test is given below.

To test the hypothesis \( H_0 : h(\hat{\delta}) = 0 \), where \( h : \mathbb{R}^p \rightarrow \mathbb{R}^j \) is a continuous vector function of \( \delta \), such that its Jacobian at \( \hat{\delta} \), \( \nabla h(\hat{\delta}) \), is finite with full row rank \( J \), the (adjusted) Wald test has the form:

\[
W = N T h(\hat{\delta})' \left[ \nabla h(\hat{\delta}) \hat{C}(\hat{\delta}) \nabla h(\hat{\delta})' \right]^{-1} h(\hat{\delta}) \overset{\mathcal{L}}{\sim} \chi^2_{(J)}
\]  

(13)

where \( \hat{\delta} \) is an estimate of \( \delta = A(\hat{\delta})^{-1} B(\hat{\delta}) A(\hat{\delta})^{-1} \), with matrices

\[
A = \left\{ E \left( \frac{\partial^2 \log L}{\partial \delta_i \partial \delta_j} \right) \right\} ; \quad B = \left\{ E \left( \frac{\partial \log L}{\partial \delta_i} \frac{\partial \log L}{\partial \delta_j} \right) \right\}
\]

Matrix \( B \) is estimated by a statistic with equal expectation. It is computed as the covariance of the analytic gradients (see Berndt et al, 1974). Matrix \( A \) is computed using analytic second derivatives. The test differs from the usual Wald test in the construction of the matrix \( \hat{C} \). In the presence of misspecification of the probability model, the likelihood ratio test is not asymptotically equivalent to the adjusted Wald test, and it is not even distributed as a \( \chi^2_{(J)} \).

All \( t \)-statistics presented below are computed based on the variance-covariance matrix \( \hat{C} \).
References


Instituto de Seguros de Portugal, *Estatísticas da Actividade Seguradora - Elementos Estatísticos I*, several years.

Instituto de Seguros de Portugal, *Estatísticas da Actividade Seguradora - Elementos Estatísticos II*, several years.


