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DECOMPOSITION OF DYNAMIC OLIGOPOLISTIC CONDUCT AND MARKET FUNDAMENTALS: THEORY AND APPLICATION TO BANKING*

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Abstract

We propose a model in which the dynamic conduct (mark-up) of an imperfectly competitive industry is the outcome of two major components: (i) dynamic oligopolistic conduct, and (ii) dynamics of market fundamentals. The model is specified such that oligopolistic dynamics are well defined and can be singled out and separated from the dynamics of fundamentals. The decomposition methodology is applied to the performance of an imperfectly competitive financial intermediation industry. Results indicate that conduct measured according to the model (i.e., when fundamentals are filtered out) substantially differs from the 'traditional' measure of conduct.

Keywords: Oligopoly, Conduct, Dynamics, Fundamentals, Banking.

JEL classification: L13, L16, G21

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1. Introduction

The interest in markup fluctuation for the study of industrial organization and macroeconomics is increasingly growing. The prime interest of this paper is to present and estimate a model capable of attributing markups to oligopolistic conduct by filtering out changes in markups which are due to factors not part of the decision rule of the firm.

We present a model which decomposes changes in economic rents into changes emanating from the dynamics of various firm, industry, and macroeconomic characteristics henceforth termed "*fundamentals*", and those emanating from oligopolistic dynamics.[1]

Imperfect competition and firm/industry conduct has been the focus of numerous studies for many years. Evidence on the existence of market power in the US economy, for instance, has been documented recently in Hall (1988) and Roeger (1995). This evidence relies on measurement of a markup existing in various sectors in the economy. The issue we are concerned with in this paper is the extent to which the measured markup reflects the dynamics of conduct rather than that of market fundamentals. Domowitz (1993) p. 215, articulates it as follows "Attributing observed departures of price from marginal cost to generic descriptions of imperfect competition or market power can be seriously misleading".[2]

Various supply, demand, institutional characteristics, and factors which might bring about market failure, may mask the true conduct of firms and industries and thus contribute to inaccurate conclusions regarding conduct. Stiglitz (1984) e.g., elaborates on the existence of positive markups in perfectly competitive environments stemming from factors such as imperfect information to changing demand elasticities over the business cycle. Natural monopoly is another example: if a firm

[1] In Section 5 we define fundamentals in a precise manner.

[2] Borenstein, Bushnell, and Wolak (1999) show, in the context of electricity markets, that if opportunity cost exceeds that of production cost, positive markup is not by itself proof of market power abuse.

operates under conditions of non-constant returns to scale, the estimated markup might be partially an artifact of these conditions and the resulting estimated conduct might be "contaminated" by this characteristic.[3] Another example can be found in the financial sector where characteristics such as asymmetric information, risk considerations, adverse selection, and moral hazard may induce an apparent imperfectly competitive conduct.[4] At the industry level, the state of the economy has an important role in shaping the economic environment and consequently, cyclical phenomena exert influence on the sectorial dynamic behavior of market power. In fact, various recent analyses pertaining to the profitability of banks document very low explanatory power when ignoring changes in fundamentals; see for instance, Berger (1995) who documents R^2 values which are almost all less than 0.2. In a recent article Berger and Mester (2001) when controlling for some fundamentals increase the explanatory power to $R^2 = 0.4$. Some other recent studies, (Humphrey and Pulley (1997) and Valverde, Humphrey, and Fernandez (2001)) report important influences that fundamentals (not banks' decision rules) exert on bank costs and profitability. Berger and Mester (2001) document important influence exerted by change in the fundamentals they specify.[5]

The prime purpose of this paper is to offer a methodology for the decomposition of markup dynamics into its fundamentals-driven component and its conduct induced component. This may be an important task from policy perspective, as policy instruments are much more prone to affect oligopolistic dynamics than the

[3] As Klette and Griliches (1996) argue, "one problem with the empirical research...is that the estimated markup is critically dependent on the assumption of constant returns to scale. If the firms in fact are operating with short run decreasing returns to scale, their markup estimates might be an artifact due to the erroneous assumption of constant returns" (p.3). Berg and Kim (1994) show that the measurement of firm's technology and efficiency is crucially dependent on the (non) treatment of conduct.

[4] In a recent analysis of the relationship between market power and bank risk, Covitz and Heitfield (1999) find that the seriousness and degree of a bank's moral hazard determines the direction of the price-cost margins.

[5] Humphrey and Pulley (1997), Berger and Mester (2001) and Valverde, Humphrey, and Fernandez (2001) use terms like "external business environment" or "economic (business) conditions" to represent externally initiated adjustments, which we term fundamentals.

dynamics of fundamentals.

It is well known that perfect competition in some sectors, the financial sector is one example, may lead to a non-optimal number of firms (see Gale (1992) for a discussion related to the optimal number of banks).[6] In fact, conduct, as measured by conventional price-cost margins, in such sectors may not even be a normative benchmark as far as public policy is concerned. These and other characteristics are inherently intrinsic to the conduct of many industries independently of their (alleged) oligopolistic conduct. Thus, one would eventually want to separate out outcomes which are the result of the above mentioned structural characteristics (fundamentals) from results which are due to oligopolistic conduct.

We present a model capable of decomposing changes in economic rents into changes emanating from market fundamentals and those emanating from oligopolistic dynamics. Prices (or economic rents) are affected directly by changes in market fundamentals and indirectly by changes in market arrangements which themselves emanate from changes in these fundamentals. Note that market arrangements give rise to oligopolistic dynamics. Market fundamentals give rise to Cournot equilibria (Friedman (1971), Green and Porter (1984)) in which variations in prices reflect either changes in technology and operating costs or changes in the demand for the product.

The paper is organized as follows. A brief discussion of related issues is presented in Section 2. A dynamic model of a generic industry is presented in Section 3. The dynamic characteristics of an oligopoly are described in Section 4, and the decomposition methodology in Section 5. The model is applied to the financial intermediation sector in Section 6, and the empirical methodology and results are discussed in Section 7. Section 8 concludes the paper.

[6] As is noted in Gale (1992), when switching costs and non observable quality of banking services are considered, it may not be clear that competition in its most desirable form can be identified with a large number of small banks.

2. Discussion

Many studies have examined the nature of markup fluctuations over the business cycle (Haltiwagner and Harrington (1991), Chevalier and Scharfstein (1996), Rotemberg and Saloner (1986), Rotemberg and Woodford (1992), Domowitz, Hubbard, and Petersen (1986), Carlton (1997), to mention a few). For changes in markups to occur one needs to appeal to some form of market failure or to some form of oligopolistic conduct in order to generate discrepancy between price and marginal cost. As is observed, there are changes in the behavior of markups which are negatively correlated with the business cycle. Chevalier and Scharfstein (1996), for instance, draw upon the effects of capital-market imperfections on product-market competition to show that markups are countercyclical because firms may be less able to collude during booms. Firms may change their behavior during the business cycle by colluding, rationing their outputs and the like. We are concerned with the separation between the cyclical part of markups and that of the effect of oligopolistic behavior influence on markups.

Generally in the literature, a (model) specific and exact nature of imperfect competition is specified in order to arrive at specific predictions for the dynamic behavior of prices and markups. It is well known though, that a wide range of price and markup dynamic behavior can be generated by game-theoretic models. Thus, outcomes regarding cyclical behavior of prices and markups may well be model-specific. Such is the case with the celebrated empirical model by Porter (1983) who used a switching regression technique applied to time series data on the Joint Executive Committee (JEC) railroad cartel form 1880 to 1886, to empirically test the Green and Porter (1984) model, or in Ellison (1994) who reexamines the role of JEC to assess the applicability of the Porter (1983) model. The major advantage of these particular models is in the existence of detailed information regarding the actual market conduct to which the model's performance and predictions can be compared and assessed. However, in the absence of such detailed information it would rather be useful to construct an empirical specification which does not rely on modelling a specific and stylized games.

Also, the empirical application of some of the aforementioned models may require the problematic specification of proxies for market power. In a recent article, Corts (1999) provides interesting criticism regarding the use of the conduct parameters method in dynamic oligopoly models.[7] Furthermore, when interest is focused on the role played by imperfect competition on prices and markups, as is the case in the recent business cycle literature (Carlton (1997), Hall (1988), Silvestre (1993)), one has to realize that price and markup fluctuations may result from two broadly-categorized interrelated sources. One such source is the changes in the economy's fundamentals as shown in Bils (1989) for the case of a change in demand elasticities, or Ghosal (2000) for changes in both supply and demand. Another source emanates from changes in the dynamics of oligopolistic conduct as demonstrated in Rotemberg and Saloner (1986), Rotemberg and Woodford (1992), and Haltiwagner and Harrington (1991), for the case of tacit collusion. Chevalier, Kashyap, and Rossi (2000) find that the pattern of margin changes they observe can better be empirically explained by retailer advertising competition which, of course, are a function of fundamentals such as the state of demand.[8] Given that markup dynamics are the result of these two interrelated sources, it is apparent that one would want to filter out the dynamics of fundamentals from the measured (total) markup-dynamics in order to separate out and identify the behavior of (oligopolistic) conduct-dynamics. This is exactly the aim and scope of the present paper.

[7] Chirinko and Fazzari (1994) use the Lerner index and Ghosal (2000) employes concentration ratios both of which may or may not accurately depict market power. Genesove and Mullin (1997) have recently shown that estimates of the conduct parameter obtained by standard methodology differs from that obtained from a direct measure of markup although, in their application, it is not quantitatively important.

[8] We should emphasize that Chevalier, Kashyap, and Rossi (2000) are able to test their proposed model by nesting it along with cyclical firm-conduct (tacit collusion) models a la Rotemberg and Saloner (1986) and Rotemberg and Woodford (1992) and those a la Bils (1989) which draw on demand elasticities.

The approach taken in this paper differs from the approaches taken in the aforementioned literature in that the dynamics of markup is specified as a stochastic process characterized by discrete changes.[9] Specifically, we specify a (quasi) Bronwnian Motion (as in Krugman (1991)).[10] This approach seems attractive since firms' decision to not cooperate or collude is induced by discrete structural changes generated by the fundamentals. Green and Porter (1984) describe discrete shifts in conduct between collusive and non-cooperative pricing regimes. As long as prices are below the trigger price, firms revert to a Cournot equilibrium. As we saw above, in the existing models conduct depends, for instance, on the state of demand.[11] These structural changes affect the moments of the underlying distribution that govern the stochastic process of the fundamentals. Thus, it seems very reasonable that these structural changes which are triggered by the fundamentals is the triggering mechanism for the change in (oligopolistic) behavior. In accordance with this notion, we adopt the following criterion for the decomposition: that part of price-dynamics which is linearly related to the univariate representation of the fundamentals is defined as the Counot price equilibrium. Deviations from this equilibrium are defined as oligopolistic dynamics. That is, the price-dynamics is decomposed into a part in which the effect of the fundamentals on the price is constant and into a part where it varies.

To reiterate, the advantage of the present specification is in that we do not have to restrict ourselves to a particular type of a game. In our model, the type of oligopolistic behavior is picked up by the deviation of the price from the "Cournot equilibrium" path generated by the fundamentals. Thus, it represents the com-

[9]It is beleived that changes in banks decission rules are not continuous but rather discrete. Humphrey and Pulley (1997) for instance, average their data for individual banks over three successive four-year intervals believing " it unrealistic to assume that profit maximizing behavior is manifested annually".

[10]Krugman (1991) and Svensson (1991) use this technique to model exchange rate dynamics.

[11]In Chevalier, Kashyap, and Rossi (2000), supermarkets decissions regarding the type of goods to advertise (and commit to a low price) depends on the states of demand and consumers reservation price in each of the states.

ponent of the price which is accounted for by oligopolistic dynamic considerations only. As discussed earlier, this is important since the nature and type of games may not be static. Furthermore, different specification of games may give rise to different cyclical behavior of markups and prices. In the Green and Porter (1984) and Haltiwagner and Harrington (1991) models e.g., markups are predicted to be procyclical whereas in models like Rotemberg and Saloner (1986) and Rotemberg and Woodford (1992) they are likely to be countercyclical.

3. The model

Consider a (discrete-time) dynamic model of an oligopolistic industry that consists of $j = 1, ..., n$ firms, each of which produces q_j units of output. We assume that firms are competitive in the factor markets. The firms' environment is characterized by a marginal cost function defined on the input prices vector $\mathbf{w}$, output q_j, a vector of other factors affecting technology $\mathbf{x}$, and a supply disturbance μ. Firm j's marginal cost function (mc_j) is therefore,

$$mc_j = mc(q_j; \mathbf{w}, \mathbf{x}, \mu). \tag{3.1}$$

Aggregate demand, D, is determined by consumers who pay a price p for a unit of the product, and whose aggregate income is I. The demand function is then,

$$D = D(I, p, \mathbf{z}, v), \tag{3.2}$$

where $\mathbf{z}$ is a vector of other demand factors (e.g. prices of other goods and services), and v is a random variable with a known distribution, affecting the demand. Marginal revenue is derived from (3.2) as,

$$mr_j = mr(q_j; I, \mathbf{z}, v). \tag{3.3}$$

The equilibrium market clearing condition is:

$$\sum_j q_j = D. \tag{3.4}$$

In this imperfectly competitive industry, firms maximize profits by producing a quantity sold at the resulting market price. That is, $mc_j(\cdot) = mr_j(\cdot)$. We assume that at any given date the realization of the random variables μ and v are known prior to any decision making. However, future realizations of μ and v are unknown. In what follows we define $\mathbf{h}$ to be a vector comprising all exogenous variables appearing in (3.1) and (3.3) including the stochastic element γ which is the reduced-form disturbance of μ and v (henceforth referred to as the vector of *fundamentals*.) That is,

$$\mathbf{h} = \{\mathbf{w}, \mathbf{x}, I, \mathbf{z}, \gamma\}. \tag{3.5}$$

4. Dynamic Characteristics in Oligopoly

In making their choices, firms consider the entire future. Therefore, in an oligopolistic dynamic context, when a firm maximizes its profits, it is well aware of its rivals' future reactions. For instance, when a firm contemplates output expansion, it is aware this may cause rivals to follow suit and consequently reduce future prices. Thus, the firm may refrain (at least to some extent) from such a strategy. These dynamic characteristics imply that the quantity supplied by firm j depends on the perceived future reaction by other firms $\partial q_i / \partial q_j$, $\forall\ i$, given all information known up to date t (t not included). The aggregate effect on price of all reactions are summarized by the following,

$$dp = \sum_j \sum_k \frac{\partial p}{\partial q_j} \frac{\partial q_j}{\partial q_k} dq_k, \tag{4.1}$$

thus capturing the rivals' reaction by dp_t yields the following output function:

$$q_{jt} = q\left[\mathbf{h}_t,\ E_t\left\{dp_t\right\}\right], \tag{4.2}$$

where E_t is the expectation operator based on period t information set, namely, firms form their expectations on the basis of all relevant and known information.[12]

[12] The information set includes, among other things, firms' beliefs on oligopolistic dynamics.

We note that the fundamentals $\mathbf{h}_t$ affect q_{jt} in (4.2) both directly and indirectly through dp_t.

5. A Decomposition Methodology

We now consider a log-linear approximation of equations (3.1)-(3.3), and (4.2) and apply the equilibrium condition (3.4), to obtain the following differential equation[13],

$$p_t = f(\mathbf{h}_t) + \beta_0 E_t \{dp_t\}, \tag{5.1}$$

where f is a univariate reduced form of the model's structure relating the vector of fundamentals $\mathbf{h}_t$ to the price p_t. Following our decomposition criterion (see Section 2) we define the second term in (5.1) as *"oligopolistic dynamics"*. In this pricing function (5.1) $\beta_0 = 0$ is a necessary and sufficient condition for $dp/df = 1$, indicating that the effect of fundamentals on prices is constant. In accordance with our decomposition criterion, and given our definition for oligopolistic dynamics, the coefficient β_0 measures the impact of oligopolistic dynamics on price. In the absence of such dynamics $\beta_0 = 0$.

Since f is the underlying stochastic process for the differential equation (5.1), the expected change in f determines the expected reaction function. Thus, the effect of oligopolistic dynamics on the price is generated through their effect on the parameters that determine the solution dp/df for the stochastic differential equation (5.1).

Since we consider dynamic time series behavior, we measure the price changes over time and rewrite (5.1) as:

$$p_t = f_t + \beta E_t \left\{ \frac{dp_t}{dt} \right\}. \tag{5.2}$$

In what follows, we assume standard properties regarding the stochastic process governing the random variable f. Utilizing these properties enables us to separate

[13] The additivity in (5.1) emanates from the separability in (4.2).

out the effect of the fundamentals from the total expected price change. We then decompose the process of the expected price change into two components: (i) the expected change emanating from the fundamentals and, (ii) the expected change due to oligopolistic dynamics.

A firm's decision whether to cooperate is affected by discrete structural changes in the fundamentals. Technical change, or a change in the exchange rate regime are only two examples of such changes. These structural changes affect the moments of the underlying distribution that govern the random processes of the fundamentals. We assume that f follows a quasi (δ, σ) Brownian Motion (Krugman (1991) and Svensson (1991)), that is:[14]

$$f_t = f_0 + \delta t + \sigma x_t, \tag{5.3}$$

where x is a quasi Wiener process with:

$$E_t \left\{ x_{t+s} \right\} = 0 \quad and \quad E_t \left\{ x_{t+s} x_t \right\} = 0 \quad \forall s > 0, \tag{5.4}$$

and

$$E_t \left\{ x_{t+s}^2 \right\} = \begin{cases} s - \frac{\delta^2}{\sigma^2} s^2 & for \qquad 0 \leq s \leq .5 \frac{\sigma^2}{\delta^2} \\ s & \qquad otherwise \end{cases} \tag{5.5}$$

Following this already well established technique (Pessach and Razin (1994)), we express the price as a function of the fundamentals, $p = p(f)$. Approximating this relationship by Taylor's expansion we get:

$$p\left[f_t\right] = p\left[f_0\right] + p_f(f)\left[f_t - f_0\right] + .5 p_{ff}(f)\left[f_t - f_0\right]^2, \tag{5.6}$$

where p_f and p_{ff} are the first and second order partial derivatives of p with respect to f, respectively. Substituting (5.3) into (5.6), taking expectations and dividing through by t, yields, for t small enough:

$$E_0 \left\{ \frac{p\left[f_t\right] - p\left[f_0\right]}{t - 0} \right\} = p_f\left[f_t\right]\delta + .5 p_{ff}\left[f_t\right]\sigma^2. \tag{5.7}$$

[14] We say that the process is quasi Brownian because of the definition of the process x, which differs in its second moment from the definition of a Wiener process. However, with zero drift $(\delta = 0)$, f is a Brownian motion process and x is a Wiener process. See also Svensson (1991) for the application of Brownian motion in the context of exchange rate and interest rate variability.

We now take the limit of (5.7) with respect to t. Substituting it into (5.2) yields the following second order differential equation:

$$p(f) = f + \beta\delta p_f + \beta\sigma^2 p_{ff}. \tag{5.8}$$

The general solution to (5.8) is:[15]

$$p(f) = f + \beta\delta + G_1 e^{(\theta_1 f)} + G_2 e^{(\theta_2 f)}, \tag{5.9}$$

where θ_1 and θ_2 are the roots of the following associated second order equation,

$$\theta^2 + 2\frac{\delta}{\sigma^2}\theta - \frac{2}{\beta\sigma^2} = 0. \tag{5.10}$$

G_1 and G_2 in (5.9) are constants of integration, and will be determined subsequently. The fundamentals consist of variables which are non-firm specific. Therefore, these variables do not display information on interfirm rivalry.

The first two terms in (5.9), $f + \beta\delta$, represent an equilibrium path for the price in terms of the fundamentals, where no market structure dynamics enter the firm's strategic choice. Notice that at this solution dp/df is a constant (equals one) and therefore, is well foreseen. In exactly this respect we refer to this solution as the "Cournot equilibrium". The rest of the right hand side of (5.9), $G_1 e^{(\theta_1 f)} + G_2 e^{(\theta_2 f)}$, describes the deviations of the price from this Cournot equilibrium. It represents the component of the price which is accounted for by oligopolistic dynamic considerations, including interfirm rivalry. This decomposition enables us to empirically observe the dynamic path of both the fundamentals and the oligopolistic components, and will subsequently be employed in the applied model.

6. The Applied Model

In order to demonstrate the applicability of the proposed model we apply it to the financial intermediation sector in which there are lenders, borrowers and financial

[15] See Appendix A for derivation.

intermediaries. Individuals supply deposits in accordance with their savings and transaction activities. The reduced-form supply is thus:

$$DEP_t^s = a_0 + a_1 y_t + a_2 r_{d_t} + a_3 r_{m_t} + a_4 r_{f_t} + a_5 e_t + a_6 pop_t + a_7 pi + \mu_t, \quad (6.1)$$

where DEP_t^s is the public's supply of deposits, y is the index of leading indicators of economic activity, r_d is the real interest on deposits representing the real return on deposits, and r_m is the nominal interest rate on monetary loans as determined by the central bank. r_f is the dollar libor rate, e is the rate of change of the real exchange rate, pop is population, pi is rate of change of the consumer price index representing the rate of inflation and μ is the supply disturbance. The coefficients a_1, a_2, a_3 and a_6 are expected to be positive. a_4, a_5 and a_7 are expected to be negative.[16] The y appears in the equation to capture wealth and transaction motives. r_m represents preferences for short-term deposits in case of a contractionary policy and vise versa. The libor r_f as well as the change in real exchange rate e capture the substitution effect. The term pop appears in the equation to capture the structural changes in population that took place in our sample period.

Borrowers form their demand for credit (of which the financial intermediaries are the suppliers) from their earning prospects, wealth and transaction activities. The reduced-form demand is:

$$CR_t^d = b_0 + b_1 y_t + b_2 r_{c_t} + b_3 r_{f_t} + b_4 e_t + b_5 pop_t + b_6 pi + v_t, \quad (6.2)$$

where CR^d is the public's demand for credit, r_c is the real interest on credit, and v is the demand disturbance. The coefficients b_1, b_3, b_4 and b_5 are expected to be positive and b_2 is expected to be negative. The sign of the b_6 coefficient is undetermined.[17]

Each financial intermediary accepts deposits, dep_j, at the going market rate

[16] An increase in e represents a devaluation of the local currency vis a vis the US dollar.

[17] Risk averse customers reduce the demand for unindexed credit as a response to increasing inflation however, the substitution effect would dicatate an increase in demand since credit is cheaper.

and supplies credit, cr_j, such that its profit is maximized.[18] We assume imperfect competitive financial markets for credit. At equilibrium we have :

$$dep_{jt} = dep^s_{jt} \qquad and \qquad cr_{jt} = cr^d_{jt}, \quad \forall j, t \tag{6.3}$$

where

$$\sum dep^s_{jt} = DEP^s_t \qquad and \qquad \sum cr^d_{jt} = CR^d_t,$$

and a constraint that relates the quantity of loans extended (cr_{jt}) to the quantity of deposits received (dep_{jt}) for each bank such that,

$$cr_{jt} = \alpha \cdot dep_{jt} \qquad with \qquad 0 < \alpha < 1, \tag{6.4}$$

where α is exogenously determined by the authorities.[19]

In line with our model the pricing of credit depends, among other things, on the degree of competition in the market for intermediation. As noted above, we deal with an oligopolistic financial intermediation industry, where the intermediary takes account of its rivals' reaction to its own choice. Therefore, the amount of credit granted by a bank and its pricing are determined by the public's borrowing needs and the bank's operating costs, as well as by the expected future change in the interest rate that would emerge as a consequence of the rivals counteractions. *Ceteris paribus*, the larger is the expected extent of the rivals reaction (i.e., the greater the perceived elasticity of the credit demand curve facing the bank), the smaller will be the expansion of the bank's supply of credit.

The price of financial intermediation is conventionally measured by the financial spread s defined as:[20]

$$s_t = r_{c_t} - \frac{1}{\alpha} r_{d_t} + \frac{1-\alpha}{\alpha} r, \tag{6.5}$$

[18] The law of motion, described later in the paper, is such that maximizing contemporaneous profits is compatible with the maximization of the infinite sum of the discounted present and future profits. Thus, no time inconsistency exist in that respect.

[19] $\alpha = 1/(1-a)$ with a being the reserve requirement.

[20] To arrive at the markup, marginal operating costs have to be deducted from s.

where r is the real yield on the required reserves held with the central bank. In our sample period, the central bank paid a constant nominal yield of zero on the required reserve balances, therefore the real yield r equals $-p/(1+p)$ where p is the rate of inflation.

The vector of fundamentals $\mathbf{h}$ in this application is:

$$\mathbf{h} = \{\mathbf{w}, r_m, y, \alpha, r_f, e, pop, pi, \gamma\} \tag{6.6}$$

where $\mathbf{w}$ is a vector of (physical) input prices representing marginal cost (see 3.1),[21] and γ being the reduced-form disturbance of μ, v. In accordance with (4.2) we get the following credit extension function[22]:

$$cr_t^i = cr\left[\mathbf{h}, E_t\left\{ds_t\right\}\right]. \tag{6.7}$$

We now consider a log-linear approximation of the above equation, and combine it with equations (6.1)-(6.5) to get:

$$s_t = f_t + \beta E_t\left\{\frac{ds_t}{dt}\right\}, \tag{6.8}$$

where

$$f_t = \psi_0 + \psi_1 y_t + \psi_2 r_{m_t} + \psi_3 r_{f_t} + \psi_4 w_t + \psi_5 \alpha + \psi_6 e + \psi_7 pi + \psi_8 pop + \gamma_t. \tag{6.9}$$

The core of our econometric application is equation (6.8) which is estimated in the ensuing section.

7. Empirical Methodology and Results

We begin the empirical work with the estimation of equation (6.8), which is the reduced form of the model presented in the previous section. With the estimated

[21] Like Hall (1988) we make no parametric assumption about the cost function, and use the wage rate (which accounts for over 75% of costs) as a summary statistic for marginal cost. Bils (1987) uses marginal wage cost as a proxy for marginal cost in his study of cyclical behavior of marginal cost and price.

[22] Note that this is not a supply relation, but rather an oligopolistically competitive arrangement.

coefficients we proceed to compute δ and σ, using (5.3)-(5.5) where:

$$\delta = E_t\left\{f_{t+1} - f_t\right\} \qquad and \qquad \sigma^2 = \delta^2 + \text{var}\left\{f_{t+1} - f_t\right\}. \tag{7.1}$$

For demonstration we utilize quarterly data from the Israeli banking sector for the 1990.1 − 1999.4 period. Summary statistics appear in Table 7.1.

Table 7.1: Summary statistics.

Variable	Mean	Max.	Min.	Std. Dev.	Obs.
s	0.068	0.122	0.042	0.025	40
y	103.6	130.8	71.1	18.8	40
r_m	0.136	0.184	0.094	0.023	40
w	213.8	241.0	188.0	13.5	40
α	0.076	0.150	0.060	0.020	40
r_f	0.056	0.090	0.041	0.015	40
pi	0.111	0.209	0.013	0.047	40
e	−0.027	0.090	−0.140	0.058	40
pop	3833	4408	3136	357	40

s =Spread as defined in (6.5). y =Index of leading indicators of economic activity. In the long-run regression $y = ln(\text{index})$. r_m=As defined in section 6. w =Index of real wage. In the long-run regression $w = ln(\text{wage index})$. α =Average reserve requirement on commercial banking short-run deposits. r_f =As defined in Section 6. pi =The last 4 quarters change in the consumer price index. e =The real exchange rate of the Israeli Shekel against the U.S. Dollar. In the long-run regression $e = (1 + ee)/(1 + pi) - 1$, where ee and pi are the quarterly change in exchange rate and the CPI respectively. pop =Population (in thousands).

Specifically, for the interest rate spread (6.5) we use the interest rate charged on short-term loans and the interest rate paid on short-term deposits. Interest rates were modified to account for the time-variant reserve requirements (see equation (6.4)). For the fundamentals we use quarterly data where all quantity data are in constant prices.

It is important to note that our methodology requires the estimation of the coefficient β in equation (6.8). Since this coefficient is a measure of the sensitivity of the spread with respect to its expected future change, one needs to specify the process of expectation formation. One way is to employ the error correction model (ECM) which allows to relate short-run pricing to deviations from long-run equilibrium. Thus, the ECM, is consistent with cases where firms when making pricing decisions take account of the industry price deviations from the path that would have been determined by the fundamentals such as the Cournot path.

The estimation of the ECM is carried out in two stages: first the long-run equation is estimated, and in the second stage, deviations from long-run equilibrium are incorporated in the short-run relationship. Long-run (steady state) equilibrium in our model is characterized by constant conduct strategies, that is, β in (6.8) is zero. Thus, our estimated long-run relationship in the ECM is:

$$\widehat{s_t} = \widehat{f_t}. \tag{7.2}$$

where $\widehat{}$ denote estimated values.

The implied estimated short-run relationship is:

$$\frac{ds_t}{dt} = \frac{df_t}{dt} - \xi\left(s_{t-1} - \widehat{s}_{t-1}\right) + \omega_t, \qquad \xi > 0 \tag{7.3}$$

where $s_{t-1} - \widehat{s}_{t-1}$ is the error-correction term, and where ω_t is a white noise residual. Rearranging (7.3) and substituting from (7.2), we get:

$$s_t = \widehat{f_t} + \frac{1}{\xi}\frac{df}{d\left(t+1\right)} + \frac{1}{\xi}\omega_{t+1} - \frac{1}{\xi}\frac{ds}{d\left(t+1\right)}, \tag{7.4}$$

or,

$$s_t = F_t - \frac{1}{\xi}\frac{ds}{d\left(t+1\right)} + \frac{1}{\xi}\omega_{t+1}, \tag{7.5}$$

where

$$F_t \equiv \widehat{f_t} + \frac{1}{\xi}\frac{df}{d\left(t+1\right)}. \tag{7.6}$$

Equation (7.5) is the estimated form of equation (6.8) from which we derive the following: (i) F_t is the relevant univariate representation of the fundamentals, which is governed by the assumed Brownian stochastic process (Cf. section 5)[23]; (ii)

[23] Note that we allow for nonlonearities between the fundamentals and the process F_t via the second term in (7.6).

the coefficient $1/\xi$ is the estimated value for β in (6.8). Given (i) and (ii), and in accordance with (7.1) we get the estimated values for δ and σ.[24]

Estimation results are summarized in Table 7.2. All variables (excluding the structural variable α) appearing in the long-run equation were found to be non-stationary ($I(1)$) using the Augmented Dickey-Fuller Unit Root Test. All these variables were found to be cointegrated as well, using the Johansen Cointegration Test. Accordingly the residual $resl$ variable is stationary as was confirmed by the unit-root test. Note that the interest rate parity condition imposes a restriction on the explanatory variables in the long-run equation. In particular, the following relationship holds: $\log(1 + r_m) = \log(1 + r_f) + \log(1 + e) + \log(1 + pi)$. Therefore pi was excluded from the long-run equation and appears only in the short-run equation where deviation from interest rate parity exist. In the short-run equation the coefficient of the error-correction term $resl(-1)$ is negative, less than unity and statistically significant as should be. Also note that the coefficients of the short and long-run equations are consistent.

The estimated reduced form is:

$$s_t = F_t - 1.3372 E_t \{ds/dt\} \tag{7.7}$$

which is a stochastic differential equation. The solution for this equation is described below.The parameter estimates give rise to the following derived values:

$$\beta = -1.3372, \qquad \delta = -0.001431, \qquad \sigma^2 = 0.0000852.$$

With these results, the roots of the quadratic equation (A.4) are complex numbers. Therefore, we derive the polaric coordinates (λ and ϕ, see appendix) which are the parameters of the solution $s(F)$ and get:

$$s(F_t) = F_t + 0.0019 + 2\pi_1(\lambda)^{F_t} cos(\phi F_t + \pi_2) + \varphi_t, \tag{7.8}$$

[24] Note that in the calculation of δ and σ, according to eq. (7.1), we appropriately substitute f_t with the time path F_t.

Table 7.2: Interest rate spread: ECM regression results.

	Long-run (levels)			Short-run (1st diff.)		
Variable	Coefficient	t-stat.	Prob.	Coefficient	t-stat.	Prob.
$const.$	1.7057	2.12	0.04	-0.0005	-0.30	0.77
α	-0.0349	-2.49	0.02	-0.0081	0.59	0.56
y	0.0469	0.77	0.45	0.1535	2.70	0.01
$pi(-2)$				0.0797	1.67	0.11
r_f	0.9444	4.63	0.00			
$r_f(-4)$				0.6329	2.44	0.02
r_m	0.1321	1.90	0.07			
$r_m(-3)$				0.1064	3.52	0.00
w	0.3545	3.18	0.00	0.7660	2.85	0.00
e	0.0356	1.13	0.27	0.0324	1.62	0.12
$e \cdot D$				-0.0653	-1.88	0.07
pop	-0.4753	2.55	0.02	-0.8401	-3.24	0.00
$resl(-1)$				-0.7478	-3.73	0.00
$adj.R^2$	0.889			0.671		
$D.W.$	1.314			1.865		

y and w are in logs. D is a dummy variable =1 for the 1997.1 period and onward, representing the regime of reduced intervention by the central bank in the foreign exchange market. $resl$ is the residual from the long-run equation. The variables pi, r_f, r_m and e are measured by the log transformation of 1+Δ where Δ is the rate of change of the respective variable. Logarithmic transformation was applied to all explanatory variables. Note, determination of lags was done according to the conventional F test.

where π_i, $i = 1, 2$ are the equation parameters (coefficients of integration) and φ is white noise.

We now proceed to the second stage of the estimation, where we apply nonlinear estimation methodology in order to estimate the coefficients of integration in (7.8). For this estimation we utilize a Non-Linear-Least-Square technique, using the Marquardt algorithm, (Pindyck and Rubinfeld (1991)). The estimated parameters appear in Table 7.3:

We now have the complete representation of the solution to the stochastic differential equation of the interest rate spread:

$$s(F_t) = F_t + 0.0019 + 0.0026(\lambda)^{F_t} cos(\phi F_t - 11.1211)) + \varphi_t.$$

Table 7.3: Interest rate spread: second stage non-linear estimation.

Variable	Coefficient	t-stat.	Prob.
π_1	0.0013	4.51	0.00
π_2	-11.1211	-37.7	0.00
$adj.R^2$	0.383		

The solution is now decomposed as follows:

(i) $sc(F_t) = F_t + 0.0019$ is the "Cournot equilibrium" path of the interest rate spread.

(ii) $sdev(F_t) = 0.0026(\lambda)^{F_t} cos(\phi F_t - 11.1211))$ represents the deviations of the spread (from the "Cournot path") to which oligopolistic dynamics are responsible.

In Figure 1, we present the solution for the oligopolistic dynamics (conduct) $sdev(F)$. The 0.00 line represents the "Cournot" equilibrium path and $sdev(F)$ is deviations from this equilibrium path and hence represents the path of oligopolistic dynamics. Notice that at the beginning of our sample-period, this solution indicates enhanced competition (the path is below the 0.00 line). Toward the end of 1991, the path crosses the 0.00 line and stays above it almost throughout the period indicating that competition had been softened due to oligopolistic dynamics.

Although this entire exercise is designed merely to demonstrate the application of the decomposition methodology, it is worth noting some major events that seem to have brought about some of the more pronounced deviations displayed in Figure 1. However, before describing these developments, we need to make the following clarification: these developments are clearly fundamentals and thus are included as explanatory variables in the short-run regression. The decomposition separates out their "demand and supply" effects from their effect on firms' conducts. The display in Figure 1 indicates the latter effect.

We start off with the effect of the massive inflow of immigrants to Israel, beginning in the late 1989 and lasting (in high rates of immigration) for at least three years and is well noticeable in the figure. This development triggered financial intermediaries to enhance competition in order to attract immigrants' funds and new clientele, all of which resulted in a lower interest spread. The same period and in particular the year of 1990, was characterized by enhanced competition due to the alleviation of restrictions on direct foreign borrowing and lending. Local banks found themselves competing with foreign financial intermediaries in addition to their local rivals. This had also contributed to the narrowing of the interest rate spread.

Latter in this decade, there occurred developments that seemed to have worked in the opposite direction (towards softening of competition). In particular, the collapse of the stock market at the beginning of 1994, resulted in a greater extent to which the public relied on local commercial banks for financial intermediation services. There was a shift to a contractionary monetary policy towards the end of 1993 and the resulting growing demand for foreign exchange denominated loans of which the local commercial banks are the primary suppliers. Finally, since 1995 the government accelerated both the privatization of the major commercial banks and the liberalization of the foregin exchange market, a possible consequence was the lesser exploitation of oligopolistic conduct.

As noted above, the interest rate spread is decomposed into the time path $sc(F)$, which is governed by the dynamics of fundamentals and involves no oligopolistic dynamics, and to the time path $sdev(F)$, which comprises deviations of the spread due to oligopolistic dynamics. The time series of these paths as well as the spread itself $s(F_t)$ are depicted in Figure 2. There are two purposes for this display: first, it allows one to compare the relative magnitudes of the deviations. The actual interest rate spread is on average 10 times larger than the deviation of the spread from the "Cournot" equilibrium (note the dual scaling in Figure 2). Secondly, in order to gain some intuition for the difference, and perhaps the misleading results that can arise from not filtering out fundamentals from oligopolistic dynamics, it can be seen (Figure 2) that while our solution $sdev(F)$ points to a conduct of decreasing competition, in particular in the second half of the decade, while the conventional spread $s(F)$, points to dynamics of enhanced competition (downward trend).The difference between these two dynamic solutions results from the time path of the fundamentals.

8. Summary

This paper presents a methodology for the decomposition of the dynamics of economic rents such that the impact of both oligopolistic dynamics and the dynamics of fundamentals on marginal profits can be observed. Applying this procedure to the Israeli banking sector enabled us to single out periods during which competition among banks was either intensified or mitigated (relative to the Cournot equilibrium) due to oligopolistic dynamics. Results indicate a substantially different conduct once fundamentals are filtered out. If price rigidity is to exist during periods of weaker competition due to, e.g., reasons of cooperation, then we provide a tool that can be of assistance in tracking it empirically.

A. Derivation of the Differential Equation

In this appendix we derive the dynamic solution for the oligopolistic price from the specified differential equation (5.8) in the text. For convenience we rewrite this equation as,

$$p(f) = f + \beta\delta p_f + .5\beta\sigma^2 p_{ff} \tag{A.1}$$

Applying the standard way of solving differential equations, we seek two solutions: one specific solution to (A.1) and another solution to the homogeneous part of equation (A.1).

(i) For the specific solution we have,

$$p(f) = f + \beta\delta \tag{A.2}$$

(ii) For the homogeneous equation $p(f) = \beta\delta p_f + .5\beta\sigma^2 p_{ff}$ we have,

$$p(f) = G_1 e^{(\theta_1 f)} + G_2 e^{(\theta_2 f)} \tag{A.3}$$

were θ_1 and θ_2 are the roots of the second order equation,

$$\theta^2 + 2\frac{\delta}{\sigma^2}\theta - \frac{2}{\beta\sigma^2} = 0 \tag{A.4}$$

We now combine (A.2) and (A.3) to get the solution (5.9) in the text.

In case where (A.4) has complex roots we define λ and ϕ such that,

$$\lambda = e^{-\left(\frac{\delta}{\sigma^2}\right)} \tag{A.5}$$

and,

$$\phi = \left(-\frac{\delta^2}{\sigma^4} - \frac{2}{\beta\sigma^2}\right)^{1/2} \tag{A.6}$$

Notice that we also have,

$$\theta = \lambda e^{\pm i\phi} = \lambda(cos(\phi) \pm isin(\phi)) \tag{A.7}$$

Next, we let the constants of integration be $G_1 = \pi_1 e^{i\pi_2}$, and $G_2 = \pi_1 e^{-i\pi_2}$. Substituting these transformations into (A.3) yields the following:

$$p(f) = f + \beta\delta + 2\pi_1 \lambda^f cos(\phi f + \pi_2) \tag{A.8}$$

where π_1 and π_2 replace the constants of integration G_1 and G_2 .

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Figure .1: Deviations of the interest rate spread from "Cournot" equilibrium, in percentage points, for the period 1990-1999.

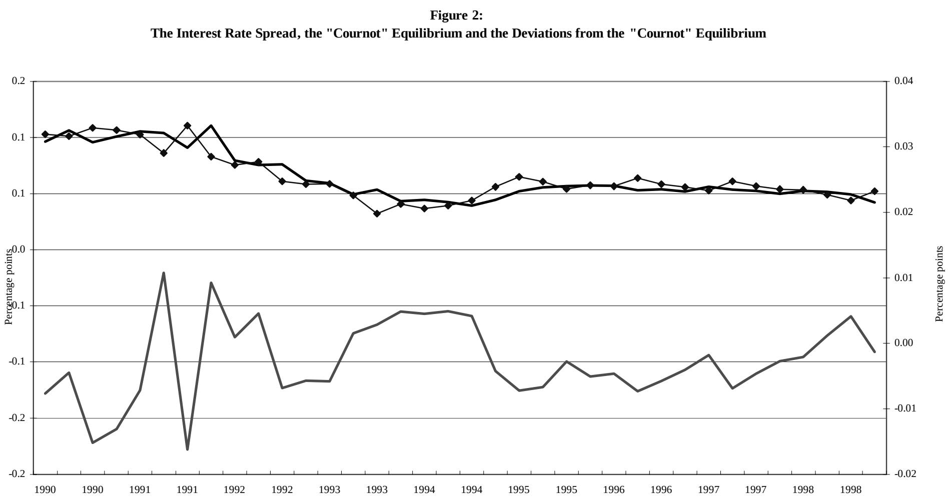

Figure .2: The values of the interest rate spread (bold line), and the "Cournot" spread (dotted line) are depicted using the right vertical axis. The deviations from "Cournot" Equilibrium is depicted using the left vertical axis. All values are in percentage points, for the period 1990 -1999.

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