Strategic Impacts of Technology Switch-Over: Who Benefits from Electronic Commerce?[‡]

Martin Bandulet*

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Abstract

The introduction of new digital production and distribution technologies may alter the firms' strategy sets, as they are not able to commit credibly to quantity strategies anymore. Mixed oligopoly markets may emerge where some companies compete in prices, while others adjust their quantities. Using an approach first published by Reinhard Selten (1971) and developed further by Richard Cornes and Roger Hartley (2001), I calculate the Nash equilibrium of such an N-person game in a linear specification. Then I discuss the strategic effect of a technology switch-over on market performance and social welfare. A firm that introduces new technology suffers a srategic disadvantage, while consumers benefit.

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*Address: Martin Bandulet, Wirtschaftswissenschaftliche Fakultät, Universität Augsburg, D–86135 Augsburg, Deutschland, Tel. +49 (0821) 598-4197, Fax +49 (0821) 598-4230, E-mail: Martin.Bandulet@Wiwi.Uni-Augsburg.DE

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1 Introduction

In recent years, a lot of research has been done to study the effects of emerging electronic coordination in the field of production and distribution on the structure and performance of oligopoly markets. Bakos (1997) discussed the consequences of reduced search costs in electronic markets. Other related papers investigate the impact of declining transport costs due to new technologies (see Morasch/Welzel, 2000), or the impact of changing cost structures as well as the increased potential for product differentiation (see Belleflamme, 2001). The present paper is dedicated to an aspect that has widely been neglected: The use of electronic coordination in production technology may change players' strategy sets and thus influence the market result.

Consider the different causes for price and quantity competition that have widely been discussed. In their seminal work, Kreps and Scheinkman (1983) describe the influence of time structure on a firm's strategy set in an oligopoly market: A player can commit himself to a quantity strategy if he has to decide about his output before sale or if the firm has to make sunk capacity investments before production. Under these circumstances, the Cournot game can be interpreted as the reduced form of a two-stage game where firms decide about capacity in the first stage and set prices in the second. Güth (1995) extends this analysis by considering a heterogenous goods market.

In a more general approach, Klemperer and Meyer (1989) assume that a company can commit to a specific supply function whose slope follows from the production technology the firm uses. As Vives (1999) elucidates, price and quantity setting behaviour can be interpreted as the extreme cases of a totally elastic or inelastic supply function and arise from different slopes of marginal costs. While flat marginal costs lead to Bertrand-like strategies, quantity strategies correspond to steep marginal costs, linked to inflexible technologies.

Obviously, the latter case corresponds to old industry—e. g. steel-works—where firms have to build huge plants before they start production. Still, similar constraints also appear for modern industries and services. Records and CDs are pressed before sale, thus producers have to decide on their circulation, first. Likewise, the network of local agencies can be interpreted as a capacity constraint for insurance companies. Banks face similar constraints, with regard to their branch offices. Besides, they are bound to legal capital restrictions.

Yet, new electronic technologies have a strong impact on both production and distribution of goods and services. Electronic commerce enables banks and insurance companies to sell their services without making use of traditional distribution channels. Internet banks buy services like emergency call centers on the market themselves, whenever needed. Thus they can react flexibly on changing demand—outsourcing enables them even to escape regulatory capital constraints (see Teske, 2002). Moreover, by using digital production it is no longer necessary to disseminate information through physical media. As a consequence, the provider of information goods—that is, publishers or music companies—may sell and distribute the plain information as a download on-line.

Hence, the use of electronic coordination—especially to produce digital goods and services—alters the production and distribution process in two important ways:

- Electronic coordination eliminates time lags between production and sale, as flexible technologies allow firms to generate goods or services on demand.
- Capacity constraints vanish since new technologies enable (almost) unrestricted replication of information goods with marginal costs close to or at zero level.

Following the reasoning above, suppliers that have already adopted such a new technology are no longer in a position to commit themselves credibly to a quantity. Instead of that, a move toward price-setting behaviour will take place. To capture the essence of this move, I will assume that these firms behave as price competitors, after they have adopted new technology. Other firms that still use old production and distribution technology have to build up capacities before production. Thus, they are assumed to set quantities.

Now consider a market where some firms have switched to new technologies, whereas others still use old technology, that is, a market with both price and quantity setters. Singh and Vives (1984) analyse a market like this in a duopoly framework, with one price and quantity setter each. Sziderovsky and Molnar (1992) provide a more general analysis of a so-called mixed oligopoly[1] and prove existence and uniqueness of the Nash equilibrium. However, their framework is not suitable to study the consequences of a technology switch-over, since they do not provide explicite results.

The model I use is based on a framework with symmetrically differentiated products. In its linear specification, it can be solved for the equilibrium by making use of recent progress in the theory of aggregative games. This approach, introduced originally by Reinhard Selten (1971) and developed further by Cornes and Hartley (2001), exploits the special structure of games where the players' payoff functions only depend on two scalars—their own strategy and the unweighted sum of the choices made by all players in the game, that is, the total aggressiveness of the game. Cornes and Hartley (2001) also state that some games may be "k-reducable", that is, players decide not on one, but on k aggregable strategy variables. In fact, I apply that extension here.

The paper is structured as follows. The next section presents the basic model. Presuming profit maximation, replacement functions and collective response curves of price or quantity setting firms will be derived to determine the Nash equilibrium of the game. Section three continues with a comparative static analysis of the equilibrium. With regard to its effect on the firm's strategy set, I discuss the implications of a technology switch on a company's own output, on its competitors and on market efficiency. Implications for investment incentives are briefly discussed in the conclusions.

[1] In another context, this expression is used to describe oligopoly markets with coexisting public and private firms (see White, 1996).

2 The Basic Model

2.1 Model Assumptions and Strategic Demand

The basic model applies a concept of symmetric product differentiation originally developed by Spence (1976) and Dixit and Stiglitz (1977). N firms[2] (indexed by $i = 1, \ldots, N$) use a linear-homogenous technology creating individual and constant marginal costs c_i to produce a specific variety of a symmetrically differentiated product x_i sold at price p_i. The demand functions for the firms' products are generated by a representative consumer with a linear-quadratic utility

$$u(x_1, \ldots, x_N) = \sum_{i=1}^{N} x_i - \frac{1}{2}\left(\sum_{i=1}^{N} x_i^2 + b\sum_{i=1}^{N}\sum_{i\neq j} x_i x_j\right) - \sum_{i=1}^{N} p_i x_i \qquad (1)$$

yielding inverse demand functions

$$p_i = 1 - x_i - b\sum_{j\neq i} x_j. \qquad (2)$$

The parameter b measures the degree of substitutability between any two products. If $b = 1$, products are perfect substitutes, whereas all firms produce independent goods if $b = 0$.

Suppose that in a simultanous move n companies ($i = 1, \ldots, n$) play Cournot strategies (that is, set quantities), while $N-n$ firms ($i = n+1, \ldots, N$) play price strategies. Seperating exogenous (strategically chosen) and endogenous prices and quantities results in the following inverse demand for a quantity adjusting firm j and a price setting firm k, respectively:

$$\begin{aligned} p_j &= 1 - b\sum_{i=1, i\neq j}^{n} x_i - b\sum_{i=n+1}^{N} x_i - x_j \\ &= 1 - b\sum_{i=1}^{n} x_i - b\sum_{i=n+1}^{N} x_i - (1-b)x_j \qquad (3) \end{aligned}$$

[2] I assume that all firms earn positive profits and actually participate in the market. However, an endogenous market entry decision that may be added in a two stage model would not change any basic results.

$$
\begin{aligned}
p_k &= 1 - b\sum_{i=1}^{n} x_i - b\sum_{i=n+1, i\neq k}^{N} x_i - x_k \\
&= 1 - b\sum_{i=1}^{n} x_i - b\sum_{i=n+1}^{N} x_i - (1-b)x_k
\end{aligned} \tag{4}
$$

Equation (4) can be transformed into a direct demand function:

$$
x_k = \frac{1 - b\sum_{i=1}^{n} x_i - b\sum_{i=n+1}^{N} x_i - p_k}{1-b} \tag{5}
$$

Summing up the $(N-n)$ demand functions of the firms using price strategies and rearranging terms, gives the total quantity produced by the Bertrand players:

$$
\sum_{i=n+1}^{N} x_i = \frac{(N-n)(1 - b\sum_{i=1}^{n} x_i) - \sum_{i=n+1}^{N} p_i}{1 + b(N-n-1)} \tag{6}
$$

After inserting this expression into (3) and (5) and denoting the aggregate of strategic price and quantity choices $\sum_{i=n+1}^{N} p_i$ and $\sum_{i=1}^{n} x_i$ by $\mathbf{P}$ and $\mathbf{X}$, respectively, the (inverse) demand functions can be written in their strategic form

$$
\begin{aligned}
p_j &= \frac{1-b}{1+b(N-n-1)} - (1-b)x_j - \frac{b(1-b)\mathbf{X}}{1+b(N-n-1)} \\
&\quad + \frac{b\mathbf{P}}{1+b(N-n-1)}
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
x_k &= \frac{1}{1+b(N-n-1)} - \frac{p_k}{1-b} - \frac{b\mathbf{X}}{1+b(N-n-1)} \\
&\quad + \frac{b\mathbf{P}}{(1+b(N-n-1))(1-b)}
\end{aligned} \tag{8}
$$

Equations (3) and (5) are now available in a form, such that the strategically chosen (exogenous) sizes appear on the right hand side, whereas endogenous variables can be found on the left hand side. Now the aggregative character of the game becomes obvious: Both endogenous output of the Bertrand players and the prices of the Cournot firms—and thus profits—only depend on their own strategy (that is, their aggressiveness) and the total sum of strategically chosen prices and quantities. According to Cornes and Hartley (2001), a game of this structure is "two-reducable", that is, it can be reduced into a system of two equations and then be solved for the Nash equilibrium.

2.2 Collective Response and the Mixed-Oligopoly Nash Equilibrium

Consider now the Cournot and Bertrand players maximizing their profits:

$$\max_{x_j} \pi_j(x_j, \mathbf{P}, \mathbf{X}) = p_j(x_j, \mathbf{P}, \mathbf{X}) \cdot x_j - c_j \cdot x_j \tag{9}$$

$$\max_{p_k} \pi_k(p_k, \mathbf{P}, \mathbf{X}) = p_k \cdot x_k(p_k, \mathbf{P}, \mathbf{X}) - c_k \cdot x_k(p_k, \mathbf{P}, \mathbf{X}) \tag{10}$$

Firm j seeks to maximize its profit by choosing quantity x_j, taking as given the aggregate quantity produced by its competitors, $\mathbf{X} - x_j$, as well as the sum of all strategic prices $\mathbf{P}$. In contrast, a firm k considers the effect of its own price decision on aggregate $\mathbf{P}$, given a fixed $\mathbf{X}$ and fixed aggregate prices of its Bertrand competitors, $\mathbf{P} - p_k$. Solving for the first order conditions, one receives firm j's and firm k's so-called replacement function $\eta_i(\mathbf{X}, \mathbf{P})$:[3]

$$x_j = \eta_j(\mathbf{X}, \mathbf{P}) = \frac{1 - b - b(1-b)\mathbf{X} + b\mathbf{P} - (1 - b + b(N-n))c_j}{(1-b)(2 - b + 2b(N-n))} \tag{11}$$

$$p_k = \eta_k(\mathbf{X}, \mathbf{P}) = \frac{1 - b - b(1-b)\mathbf{X} + b\mathbf{P} + (1 - 2b + b(N-n))c_k}{2 - 3b + 2b(N-n)} \tag{12}$$

Unlike a reaction function, η_i does not describe a player i's optimal response to his competitors' strategy choice (that is, $\mathbf{X} - x_j$ or $\mathbf{P} - p_k$, respectively), but to the total aggregate $\mathbf{X}$ or $\mathbf{P}$, which includes his own strategy choice.[4] Using the fact that in equilibrium the aggregate reaction complies with the aggregate strategy choice—so $\sum_{i=1}^{n} \eta_j(\mathbf{X}, \mathbf{P}) = \mathbf{X}$ and $\sum_{i=n+1}^{N} \eta_k(\mathbf{X}, \mathbf{P}) = \mathbf{P}$—we can solve for the strategic quantity produced and the strategic price aggregate, that is,

$$\mathbf{X} = \frac{(1-b)n + bn\mathbf{P} - (1 - b + b(N-n))\sum_{i=1}^{n} c_i}{(1-b)(2 - b + b(2N-n))} \tag{13}$$

$$\mathbf{P} = \frac{(1-b)(N-n) - b(1-b)(N-n)\mathbf{X}}{2 - 3b + b(N-n)} + \frac{(1 - 2b + b(N-n))\sum_{i=n+1}^{N} c_i}{2 - 3b + b(N-n)}. \tag{14}$$

[3]Cornes and Hartley (2001) use this expression. The greek letter η traces back to Seltens (1971) terminology *Einpassungsfunktion.*

[4]So, $\eta_j(\mathbf{X}) = R_j(\mathbf{X}_{-j})$ and $\eta_k(\mathbf{P}) = R_k(\mathbf{P}_{-k})$.

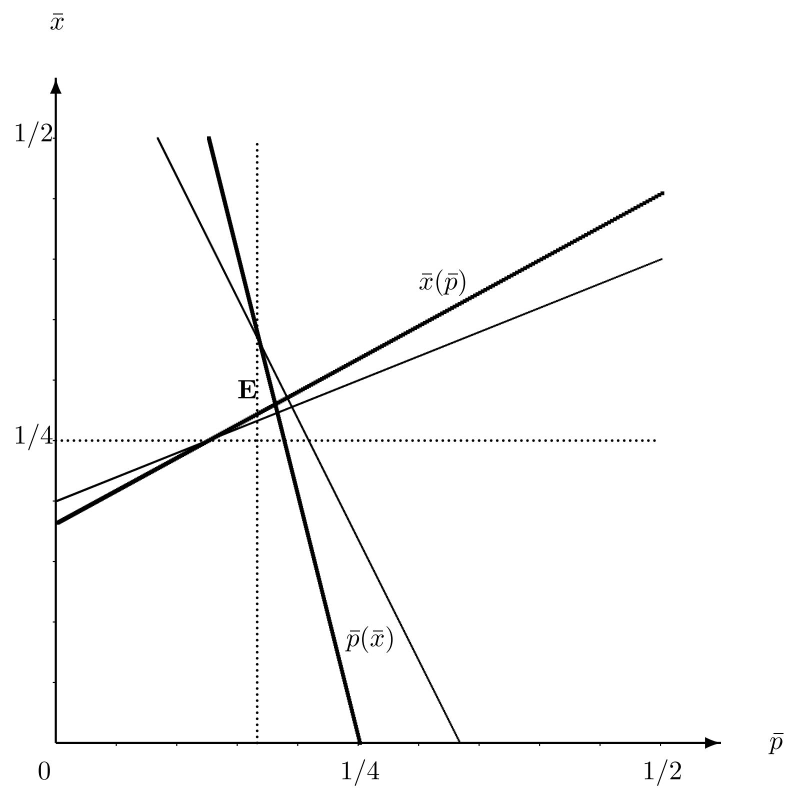

Figure 1: Collective response curves in a mixed oligopoly

Notice that the aggregate quantity decision **X** depends on the aggregate prices **P** and vice versa. Hence, the equations above may be interpreted as collective reaction functions. The graphic presentation of the mixed oligopoly (see Figure 1) displays these collective response curves of price and quantity adjusting firms (readers should notice that I have normalised them by dividing by the number of Cournot or Bertrand players respectively). The bold lines refer to an oligopoly with two Cournot players and three Bertrand firms, zero marginal costs and a value of $b = 1/2$. The intersection of the lines (E) marks the mixed Nash equilibrium in this case. The thin lines refer to an oligopoly with $n = 3$ and $N - n = 2$. I have also plotted the pure Bertrand and Cournot results into the graph (dotted lines), in order to compare the mixed oligopoly with those well known results.

The figure illustrates the relationship between the strategic price and quantity aggregates: If prices go up (so price setters play a less aggressive strategy), the Cournot players will react by increasing their output. As $\mathbf{X}$ is increasing in $\mathbf{P}$, it is a strategic substitute to $\mathbf{P}$. On the other hand, price adjusting companies will reduce their prices if quantity setters play more aggressively, hence prices of Bertrand players are strategic complements to the aggregate quantity $\mathbf{X}$.

The analytic solution corresponds to the solution of the equation system (13) and (14). Note that both response functions are linear in $\mathbf{P}$ and $\mathbf{X}$ respectively—thus a unique solution exists.

$$\mathbf{P}^* = \frac{1}{(1-b)z}\left((N-n)(1-b)(2-b+2b(N-n)) + \alpha\sum_{i=1}^{n} c_i + \beta\sum_{i=n+1}^{N} c_i\right) \tag{15}$$

$$\mathbf{X}^* = \frac{1}{(1-b)z}\left(n(1-b)(2+b(2N-2n-1)) - \gamma\sum_{i=1}^{n} c_i + \delta\sum_{i=n+1}^{N} c_i\right) \tag{16}$$

To simplify the presentation of the analytic results, I have substituted the denominator $(1-b)(4+b(6N-4n-4)) + b^2(2N(N-n)-N-1)$ by z, and I use greek letters for the factor terms of (aggregate) costs:

$$\begin{aligned}
\alpha &= b(N-n) + b^2(N-n-1) \\
\beta &= (1-b)(2+b(4N-3n-3)) + b^2((2N-n)(N-n)-(N+1)) \\
\gamma &= (1-b)(2+3b(N-n-1)) + b^2((N-n)^2-(N-n)) \\
\delta &= bn + b^2(N-n-2).
\end{aligned}$$

As can be seen by direct inspection, α, β, γ, δ and z are all positive for any $n < N$ with $N, n \in \mathbf{N}$ and $0 < b < 1$. That proposal is most obvious for big N and n. For small numbers, the reader might go and see for himself by own calculation.

Inserting (15) and (16) into (11) and (12) then results in the equilibrium output and price of a company j using a quantity strategy and a firm k that adjusts prices.

$$\begin{aligned}
x_j = {} & \frac{(1-b)[4+8b(N-n-1)+b^2(2(N-n)-1)(2(N-n)-3)]}{z(1-b)(2-b+2b(N-n))} \\
& + \frac{\epsilon\sum_{i=1}^{n} c_i + (\epsilon-b^3)\sum_{i=n+1}^{N} c_i - \phi c_j}{z(1-b)(2-b+2b(N-n))}
\end{aligned} \tag{17}$$

$$
\begin{aligned}
p_j - c_j &= \frac{(1+b(N-n))(1-b)[4+8b(N-n-1)+b^2(2(N-n)-1)(2(N-n)-3)]}{z(1+b(N-n-1)(2-b+2b(N-n))} \\
&\quad + \frac{(1+b(N-n))[\epsilon\sum_{i=1}^{n} c_i + (\epsilon - b^3)\sum_{i=n+1}^{N} c_i - \phi c_j]}{z(1+b(N-n-1)(2-b+2b(N-n))} \qquad (18)
\end{aligned}
$$

$$
\begin{aligned}
x_k &= \frac{(1+b(N-n-2))(1-b)[4+8b(N-n-1)+b^2(2(N-n)-1)(2(N-n)-3)]}{z(1-b)(1+b(N-n-1))(2-3b+2b(N-n))} \\
&\quad + \frac{(1+b(N-n-2))[\epsilon\sum_{i=1}^{n} c_i + (\epsilon - b^3)\sum_{i=n+1}^{N} c_i - \phi c_k]}{z(1-b)(1+b(N-n-1))(2-3b+2b(N-n))} \qquad (19)
\end{aligned}
$$

$$
\begin{aligned}
p_k - c_k &= \frac{(1-b)[4+8b(N-n-1)+b^2(2(N-n)-1)(2(N-n)-3)]}{z(2-3b+2b(N-n))} \\
&\quad + \frac{\epsilon\sum_{i=1}^{n} c_i + (\epsilon - b^3)\sum_{i=n+1}^{N} c_i - \phi c_k}{z(2-3b+2b(N-n))} \qquad (20)
\end{aligned}
$$

Again, I have replaced some terms, using ϵ and ϕ as substitutes. Both ϵ and ϕ are positive for admissable values of N, n and b:

$$
\begin{aligned}
\epsilon &= (1-b)[2b+b^2(4N-4n-3)] + b^3[2(N-n)^2-(N-n)] \\
\phi &= (1-b)[4+b(10N-8n-8)+b^2(4(2N-n)(N-n)-8(N-n)-3(N-1))] \\
&\quad + b^3[N(2(N-n)^2-(N-n))-(N-n)]
\end{aligned}
$$

General results do not offer any surprises. As can be expected, output and mark up on marginal costs will decline if more companies enter the market (note the increase in z). An increase in a firm's own production cost has the same impact, while rising costs of competitors lead to an opposite result: own mark-up and output increase in this case.

3 Strategic Effects of Technology Switch-Over

Using the results of the previous section, we are now able to investigate the strategic effect of electronic coordination on market performance. To simplify the exposition, I assume for the further analysis that production does not carry any costs, no matter which technology is used (that is, $c_j = c_k = 0$).[5] So, any cost effect linked to different technologies is ignored. In reality, a technology change may alter a firm's cost structure; however, it is not my intention to explain technology switch-over by cost savings.

In a first step, the market position of an old Cournot player is compared with the position of a company using a new production technology and therefore acting as a price setting company. The intention is to prove whether it is the price or the quantity setter to be in a profitable strategic situation—e. g. consider the music industry: does a firm that sells its music as MP3 download on-line earn more or less than its "traditional" rival?

The second part of this section analyses the consequences of technology switch-over, that is, a Cournot player turning into a Bertrand player: is it profitable to introduce electronic or digital production and distribution technology in the own firm from a strategic point of view, e. g. in order to supply music on-line? Hereby, the firm has to consider the effect of the own technology switch-over on the market structure. After the technology change, there is one less traditional supplier on the market, but an additional firm using electronic coordination.

3.1 Price and Quantity Strategies by Comparison

Intuitively, in a mixed oligopoly market prices of the Bertrand players are higher than prices of Cournot players with equal (zero) marginal costs. Figure 2 displays the residual demand of both players: Notice that the rivals of a Cournot player consist

[5] The key results below hold also for less restrictive assumptions. To ease the reading of this paper, I have decided to integrate the (rather short) proofs related to the simplified exposition into the continuous text, while more general results are to be found in the appendix.

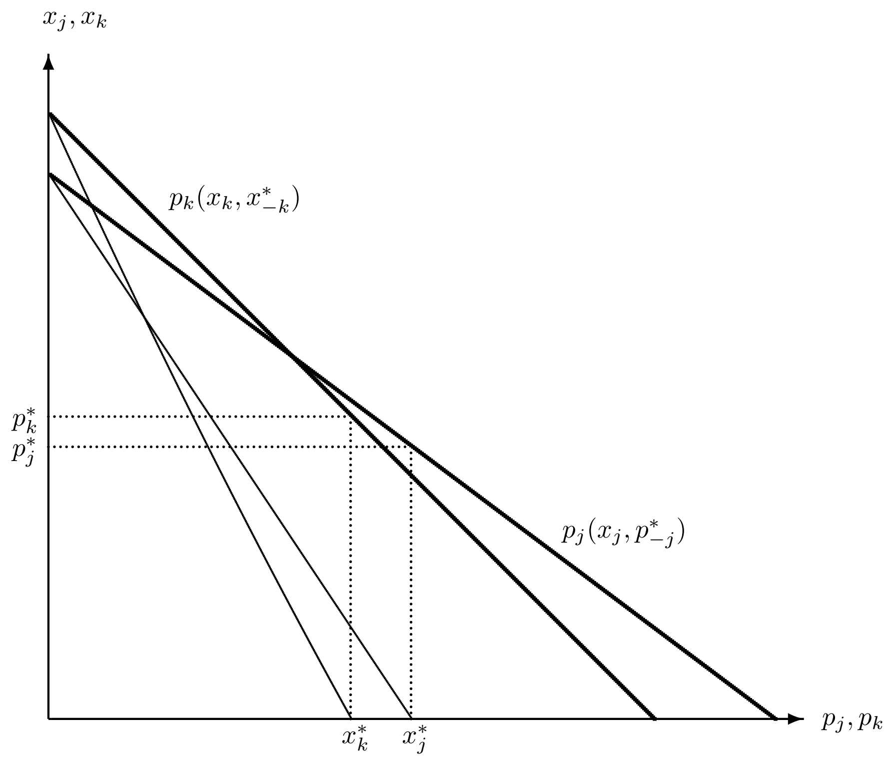

Figure 2: The residual demand of a Cournot player j vis-à-vis a Bertrand firm k

of one Cournot player less, but one additional Bertrand competitor (compared to the rivals of a price setter). For this reason, the demand function is more elastic for the Cournot firm. If this firm plays more aggressively, it can grab demand from that additional price setting firm—it is not possible to draw off demand from Cournot firms, since they have fixed their output by definition. As a consequence, marginal revenue from a price cut is higher for the Cournot players, and they will sell their outputs at lower prices than their Bertrand rivals.

Proposition 1 *Cournot players sell at lower prices than Bertrand players:* $p_j < p_k$.

Proof: The quotient of (20) and (18) shows the relation between the product prices of two firms with equal marginal costs $c_j = c_k = 0$, but different strategic situations:

$$\frac{p_k}{p_j} = \frac{(1 + b(N - n - 1))(2 - b + 2b(N - n))}{(1 + b(N - n))(2 - 3b + 2b(N - n))} \tag{21}$$

Note that this fraction has the form $(AB - bB)/(AB - 2Ab)$, with $A = 1 + b(N - n)$, $B = 2 - b + 2b(N - n)$ and b positive. The numerator exceeds the denominator, since $B < 2A$. Hence $p_k > p_j$.□

However, a comparison of profits leads to a different result.

Proposition 2 *Cournot players earn more profit than Bertrand players:* $\pi_j > \pi_k$.

Proof: Using equation (21) and the fact that from (17) to (20)

$$\pi_j = \frac{(1-b)(1+b(N-n))}{(1+b(N-n-1))} \cdot x_j^2 \tag{22}$$

and

$$\pi_k = \frac{(1+b(N-n-2))}{(1-b)(1+b(N-n-1))} \cdot (p_k - c_k)^2, \tag{23}$$

yields the proportion of the profits:

$$\frac{\pi_k}{\pi_j} = \frac{(1+b(N-n-2))(2-b+2b(N-n))^2}{(1+b(N-n))(2-3b+2b(N-n))^2} \tag{24}$$

This fraction has the structure $((A-2b)B^2)/(A(B-2b)^2)$. As can be seen easily, the denominator exceeds the numerator if $2Ab - B(2A - B) > 0$. This condition is always fulfilled for positive values of A, B and b, because $B < 2A$ and $2A - B = b$.□

Notice that a Bertrand firm earns less profit, but charges a higher price than a Cournot rival. Therefore its sales are lower. Thus, the analysis of the market position implies these results:

- In a differentiated oligopoly, comparable companies sell at different prices, depending on their use of price or quantity strategies. To be more exact, the quantity adjusting firm sells more, but at a lower price, than its price setting rival.

- The strategic quantity effect outweighs the price effect. Thus, the price setting firm is caught in an adverse situation and earns less profit than its quantity competitor.

3.2 The Impact of Technology Switch-Over

Now consider a firm that decides to introduce a new technology. The results stated above suggest that this firm suffers a strategic disadvantage in this case. Still, it has to bear in mind that the switch-over of own technology also has an impact on total market structure: The number of price adjusting firms increases to $N-n+1$, while the quantity of Cournot players on the market drops to $n-1$. This has to be taken into consideration when evaluating the impact of technology change on the own market position, market performance and social benefit.

Does a firm charge a higher or a lower price when it introduces new technology? As the technology switch-over (and therefore the switch-over of the strategy set) lets the own residual demand uneffected, that firm would not have any incentive to change its own quantity or prices if its competitors did not change their strategy. However, its competitors face a new strategic situation. From their point of view, the number of Cournot rivals on the market has decreased by one, whereas one additional Bertrand firm competes on the market. Hence, their demand becomes more elastic and they play more aggressively. As a result, prices of the rivals go down and the switching firm reacts with reduced prices. From this, it follows:

Proposition 3 *If a firm turns into a Bertrand player, it will charge a lower price than it used to receive as a Cournot player:* $p_{j,n}^N > p_{k,n-1}^N$.

Proof: Note that we have to compare the price of a Bertrand firm to a Cournot player on a market that consists of one Bertrand player less and an additional Cournot player instead. Let $p_{j,n}^N$ be the equilibrium price of a Cournot player, $p_{k,n}^N$ that of a Bertrand firm in an oligopoly market with n Cournot and $N-n$ Bertrand players. Under the assumption that $c_j = c_k = 0$, one receives from (18) and (20) after simple transformations:

$$\begin{aligned} p_{j,n}^N - p_{k,n-1}^N &= \frac{b^3(1-b)[2bN(N-n-1)+N(2+b)-2nb+3b-2]}{(1+b(N-n-1))\cdot\psi\cdot\omega} \qquad (25) \\ \text{where} \qquad \psi &= (1-b)(4+b(6N-4n))+b^2(2N(N-n)+(N-1)) \\ \omega &= (1-b)(4+b(6N-4n-4))+b^2(2N(N-n)-N-1) \end{aligned}$$

For $N > n \in \mathbf{N}$ and $0 < b < 1$, the numerator as well as ψ and ω are then positive. So $p^N_{j,n} - p^N_{k,n-1} > 0.\square$

How does a firm's profit change after the technology switch-over? To see this, first consider the remaining Cournot players.

Proposition 4 *The more Bertrand firms exist, the lower are the profits of the remaining Cournot players:* $\pi^N_{j,n} > \pi^N_{j,n-1}$.

This is coherent with the overall decline in prices, which leads to lower marginal revenue for any quantity choice.

Proof: From (17) and (22) one receives $\partial\pi_j/\partial n$:

$$\begin{aligned}\frac{\partial \pi_j}{\partial n} &= \frac{b^3(1-b)^2(2+2b(N-n)-3b)[4N-8+b((8N-4)(N-n-1)+6)]}{(1+b(N-n-1))^2 \cdot \omega^3} \\ &+ \frac{b^5(1-b)(2+2b(N-n)-3b)[4N(N-n)^2-2(N-n)(2n-1)+N+1]}{(1+b(N-n-1))^2 \cdot \omega^3}\end{aligned} \tag{26}$$

As can be seen easily, this expression is positive for all $N > 2$ and $n < N - 1 \in \mathbf{R}_+$. As the sign of the denominator is positive in the total range of $0 < n < N - 1$, the profit function has to be continous and continously differentiable there. From the sign of the numerator follows: $\pi^N_{j,n} > \pi^N_{j,n-1} \quad \forall n < N, \quad n > 2, \quad n, N \in \mathbf{N}$. Comparing profits in the two special cases, one receives that $\pi^N_{j,N} > \pi^N_{j,N-1}$ and $\pi^{[2]}_{j,2} > \pi^{[2]}_{j,1}$. $\square$

I am now in the position to state the strategic impact of a technology switch-over:

Proposition 5 *A Cournot firm turning into a Bertrand firm suffers a strategic disadvantage.*

Proof: This statement follows directly from **proposition 2** and **proposition 4**. From **proposition 4**, we know that Cournot firms earn less when the number of Cournot firms declines. From **proposition 2**, we know that Bertrand firms earn less than Cournot firms. If a firm introduces new technology, it will turn from Cournot to Bertrand competition, and the number of Cournot players on the market will be reduced by one.□

However, the impact of a strategy change on the other price setting companies is ambigous, because for close substitutes ($b > 2/3$), the output of Cournot competitors declines in this case. Due to the adverse effect of intensified aggressiveness by the price adjusting firms—it hits the quantity playing rivals more severely—, a reduction of n may even result in higher profits for Bertrand players, while the Cournot rivals earn less.

Do customers benefit from electronic commerce? At least this model framework gives a positive answer.

Proposition 6 *If one Cournot player turns into a Bertrand firm, all firms charge lower prices.*

Proof: From **proposition 1**, follows directly that $p^N_{j,n} < p^N_{k,n}$ and $p^N_{j,n-1} < p^N_{k,n-1}$. From **proposition 3**, we know that $p^N_{k,n-1} < p^N_{j,n}$. Thus we can formulate the following inequation chain: $p^N_{j,n-1} < p^N_{k,n-1} < p^N_{j,n} < p^N_{k,n}$. As can be seen by direct inspection, $p^N_{j,n-1} < p^N_{j,n}$ and $p^N_{k,n-1} < p^N_{k,n}$. □

The universal price cut, initialised by the technology switch-over, eases the representative consumer's budget constraint. Thereby, his real wealth is enlarged. While the firms that introduce electronic commerce suffer a strategic disadvantage, costumers benefit from the emergence of new digital production and distribution. Market efficiency rises as well since price mark-ups on zero marginal costs shrink.

4 Conclusion

The purpose of this paper was to show that negative strategic impacts of a process innovation on own profit occur, if in turn the company competes in prices instead of quantities when using electronic coordination in production and distribution. There are two main reasons for that: Firstly, the innovation involves a change in market structure, the number of price setting firms increases while Cournot rivals shrink. Even in a mixed oligopoly, this leads to fiercer competition. Secondly, turning into a price setting firm, it suffers a strategical disadvantage compared to its rivals. Yet, more price competition would increase market efficiency. From that point of view, one should expect too little incentives for firms to invest in new technologies of electronic coordination.

However, generalising this statement would overstress my arguments: In a broader context, one has to regard effects that go in the opposite direction. It has to be taken into consideration that new technologies are introduced precisely because costs of production can be reduced significantly. As a consequence, producers still using old technique may be driven out of the market. Intensity of competition might be reduced that way. Another objection states that electronic coordination offers vast possibilities to collect customer data. This enables companies to judge their consumers' preferences more precisely and may help to discriminate prices. A global view which includes these aspects might be the topic for further research.

Appendix

The main results of this paper persist in a less restrictive framework, where all firms produce with constant, but individual marginal costs c and earn at least zero profits. **Proposition 7** and **8** generalize **proposition 1** and **2**, while **proposition 9** and **10** include the statement of **proposition 3**. Finally, **proposition 11** and **12** include the key results of this paper that are presented in **proposition 5** and **6**.

Proposition 7 *Cournot players sell at lower prices than Bertrand players with equal marginal costs c:* $p_j(c) < p_k(c)$.

Proof: See **proposition 1**.□

Proposition 8 *Cournot players earn more profit than Bertrand players with equal marginal costs c:* $\pi_j(c) > \pi_k(c)$.

Proof: See **proposition 2**.□

Proposition 9 *If a firm turns into a Bertrand player, it will charge a lower price than it used to receive as a Cournot player:* $p^N_{j,n}(c_i) > p^N_{k,n-1}(c_i)$

Proof: Note that we have to compare the price of a Bertrand firm to a Cournot player on a market that consists of one Bertrand player less and an additional Cournot player instead. Let $p^N_{j,n}(c_j)$ be the equilibrium price of the switching Cournot player in an oligopoly market with n Cournot players, $p^N_{k,n}(c_k)$ that of the new Bertrand firm in an $(N, n-1)$-oligopoly market. Further, denote $\bar{c}_m$ the average marginal costs of the non-switching Cournot players and $\bar{c}_p$ the average marginal costs of the non-switching Bertrand firms. Under the assumption that $c_j = c_k = c_i$, one receives from (18) and (20) after simple transformations:

$$p^N_{j,n}(c_i) - p^N_{k,n-1}(c_i) = \frac{(b_0 + a_1 c_i + a_2 \bar{c}_m + a_3 \bar{c}_p) b^3}{(1 + b(N-n-1))(2 + b(2N-2n-1)) \cdot \psi \cdot \omega} \tag{27}$$

$$\begin{aligned}
\text{where} \qquad b_0 &= (1-b)(2 + b(2N-2n-1))[2Nb(N-n-1) \\
&\quad + N(2+b) - 2nb + 3b - 2] \\[1em]
a_1 &= (1-b)b[2(N-1) + b(4N(N-n) - 3(N-1))] \\
&\quad + b^3(N-n)[2N(N-n) + N - 2n + 1] \\[1em]
a_2 &= (6b-4)(n-1)[1 + b(2N-2n-1) + b^2((N-n)^2 - (N-n))] \\[1em]
a_3 &= (N-n)\big[(1-b)[-4 - b(2 + 8(N-n)) - b^2(4(N-1) + 4(N-n)^2)] \\
&\quad - b^3[2(N-n)(N+n) - N - 1 + 2n]\big]
\end{aligned}$$

Note that for $N > n \in \mathbf{N}$ and $0 < b < 1$, the denominator terms are then positive. Thus, it has to be shown that the numerator is positive for all admissable values.

Notify also the necessary constraints that average Cournot and Bertrand players sell a positive quantity, thus $x^N_{m,n-1}(\bar{c}_m) \geq 0$ and $x^N_{p,n-1}(\bar{c}_p) \geq 0$. Calculus leads to:

$$x^N_{p,n-1}(\bar{c}_p) = \frac{(1 + b(N-n-1))(b_1 + a_{11} c_i - a_{12} \bar{c}_m + a_{13} \bar{c}_p)}{(1-b)(1 + b(N-n))(2 + b(2N-2n-1)) \cdot \psi} \tag{28}$$

$$x^N_{m,n-1}(\bar{c}_m) = \frac{b_2 + a_{21} c_i + a_{22} \bar{c}_m - a_{23} \bar{c}_p}{(1-b) \cdot \psi} \tag{29}$$

$$
\begin{aligned}
\text{where} \qquad a_{11} &= b(1-b)[2+b(4(N-n)+1)] \\
&\quad + b^3[3(N-n)+2(N-n)^2] \\
a_{12} &= b(n-1)\big[(1-b)[2+b(4(N-n)+1)] \\
&\quad + b^2[1+3(N-n)+2(N-n)^2]\big] \\
a_{13} &= (1-b)[4+8Nb-6nb+b^2(4N(N-n)+n-1)] \\
&\quad + b^3[2(N-n)^2 n+3(N-n)n+n-1] \\
a_{21} &= b[1+b(N-n-1)] \\
a_{22} &= (1-b)[2+3b(N-n)]+b^2[(N-n)^2+(N-n)] \\
a_{23} &= b[(1-b)(N-n)+b(N-n)^2] \\
b_1 &= (1-b)[4+8b(N-n)+b^2(4(N-n)^2-1)] \\
b_2 &= (1-b)[2+b(2N-2n-1)]
\end{aligned}
$$

Now consider the problem

$$
\begin{aligned}
&\min_{c_i,c_p,c_m} p^N_{j,n}(c_i) \;-\; p^N_{k,n-1}(c_i) \qquad (30) \\
\text{s.t.} \qquad & x^N_{m,n-1}(\bar{c}_m) \;\geq\; 0 \\
& x^N_{p,n-1}(\bar{c}_p) \;\geq\; 0
\end{aligned}
$$

Since the denomiator terms of $x^N_{m,n-1}(\bar{c}_m)$ and $x^N_{p,n-1}(\bar{c}_p)$ are positive, this problem can be transformed into the following standard linear optimization problem that can be solved using the simplex method:

$$
\begin{aligned}
&\max_{c_i,c_p,c_m} - b_0 - a_1 c_i - a_2 \bar{c}_m - a_3 \bar{c}_p \qquad (31) \\
\text{s.t.} \qquad & - a_{11} c_i - a_{12} \bar{c}_m + a_{13} \bar{c}_p + s_1 = b_1 \\
& - a_{21} c_i + a_{22} \bar{c}_m - a_{23} \bar{c}_p + s_2 = b_2 \\
& c_i, \bar{c}_m, \bar{c}_p \geq 0 \qquad s_1, s_2 \geq 0 \qquad (32)
\end{aligned}
$$

As a result, both side conditions are binding for $c_i = 0$ and identical marginal costs of Cournot and Bertrand players:

$$\bar{c}_m = \bar{c}_p = \frac{(1-b)(2+b(2N-2n-1))}{2+2b(N-n-1)-b^2(N-n)} \tag{33}$$

The minimum value of the objective function is zero. Thus, $p^N_{j,n}(c_i) - p^N_{k,n-1}(c_i)$ is strictly non-negative. $\square$

Proposition 10 *Assume two Cournot firms with different marginal costs c_j and c_m and two Bertrand firms with different marginal costs c_k and c_p. Further, assume $c_j = c_k = c_i$ and $c_m = c_p = c_r$. Then, the difference between the prices of the two Cournot firms in an (N,n)-oligopoly market and the difference between the prices of the two Bertrand companies in an $(N,n-1)$-oligopoly market are equal: $p^N_{j,n}(c_i) - p^N_{m,n}(c_r) = p^N_{k,n-1}(c_i) - p^N_{p,n-1}(c_r)$.*

Proof: By calculation, one receives

$$p^N_{j,n}(c_j) - p^N_{m,n}(c_m) = \frac{(c_j - c_m)(1+b(N-n-1))}{2+b(2N-2n-1)} \tag{34}$$

$$p^N_{j,n}(c_k) - p^N_{m,n}(c_p) = \frac{(c_k - c_p)(1+b(N-n-1))}{2+b(2N-2n-1)} \tag{35}$$

Note the equivalence for $c_j = c_k = c_i$ and $c_m = c_p = c_r$. $\square$

Proposition 11 *If one Cournot player turns into a Bertrand firm, all firms charge lower prices.*

Proof: From **proposition 7**, follows directly that $p^N_{m,n}(c_r) < p^N_{p,n}(c_r)$ and $p^N_{m,n-1}(c_r) < p^N_{p,n-1}(c_r)$. From **proposition 10** and **proposition 9**, we know that $p^N_{p,n-1}(c_r) < p^N_{m,n}(c_r)$. Thus we can formulate the following inequation chain: $p^N_{m,n-1}(c_r) < p^N_{p,n-1}(c_r) < p^N_{m,n}(c_r) < p^N_{p,n}(c_r)$. As can be seen by direct inspection, $p^N_{m,n-1}(c_r) < p^N_{m,n}(c_r)$ and $p^N_{p,n-1}(c_r) < p^N_{p,n}(c_r)$. $\square$

Proposition 12 *A Cournot firm turning into a Bertrand firm suffers a strategic disadvantage.*

Proof: Inserting (6) into (3) and rearranging the terms, gives the residual demand $x_j(p_j, \sum_{i=1,i\neq j}^{n} x_i, \sum_{n}^{N} p_i)$:

$$x_j(p_j, .) = \frac{(1-b) - (1-b)b\sum_{i=1,i\neq j}^{n} x_i + b\sum_{n}^{N} p_i}{(1-b)(N-n+1)} - \frac{1+b(N-n+1)}{(1-b)(N-n+1)}p_j \quad (36)$$

Note that an own strategy switch-over lets the slope of the own residual demand function $x'_j = \partial x_j / \partial p_j$ unchanged. However, from **proposition 9** we know that the switching firm j lowers its price, when playing a Bertrand strategy instead of a Cournot strategy. From the standard profit maximizing argument, we know that the optimal mark-up on marginal costs is $p_j^* - c_j = x_j(p_j, .)/x'(x_j)$. Hence, a switch to Bertand strategy reduces not only j's mark-up, but also his output. Consequently firm j's profit declines. □

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