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Purchase Price Control in High-Tech Product Markets under Competition of Suppliers with Multi-Channel Production Capacities

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Abstract: The strategic control of the purchase price for high-tech products and market competition is considered. For this purpose, a new bilateral oligopoly market model is proposed. The new model allows determining the purchase prices for high-tech products under the competition of suppliers with flexible production capacities. Parametric calculations of the purchase prices, the number of competing suppliers and their production capacities are performed depending on the unit price offered by the monopsonist customer. The purchase prices offered by the customers to guarantee the competitiveness of the market are determined. The customers' optimal pricing policy that will reduce the purchasing costs and/or ensure the existence of competing suppliers in the long run is identified. A possible price reduction for high-tech products when applying this policy is calculated. The ranges of some characteristic market parameters (the capital-output ratio, the rates of order execution and order flow, and the number of potential order sources) for which this policy is efficient are determined.

Keywords: strategic control of purchase prices, bilateral oligopoly market model, suppliers competition, production capacity, customer pricing policy

1. INTRODUCTION

As a rule, the customers and suppliers in high-tech product markets include one or several key players. In other words, these markets represent either a bilateral oligopoly, or a unilateral monopoly, or a unilateral monopsony; see a generally accepted classification in [7]. Due to the strict budget constraints, it is necessary to reduce the costs of developing and manufacturing high-tech products. Among other things, the high-cost prices of such products are due to the great market power of the suppliers. As a result, the prices for high-tech products are overstated, their quality is decreased, and the delivery times are violated. The monopolistic position of some manufacturers demotivates the adoption of advanced technologies, i.e., the institutional factors of product price increase amplify the effect of the technological factors. Contrary to expectations, the great market power of the government as the main customer (for example, in the defense industry) does not guarantee low purchase prices. Even if this market represents a monopsony (which occurs in the absence of exported products), there are usually only one or few potential suppliers. Therefore, the buyer's great market power is balanced by the great market power of the suppliers. The same applies to the markets of components. Many markets of final defense industry products and their components are monopolized, primarily due to the degradation of many manufacturers during the almost 20-year crisis period. (In the Soviet era, all manufacturers competed with each other for the right to develop and produce their products). In other words, the customers' market power is at least balanced by the suppliers' market power. The natural problems are therefore to keep the competing suppliers in the industry and simultaneously encourage new suppliers to enter the market. This paper attempts to solve the first problem

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(keeping the competing suppliers in the market in the long run) via an appropriate customer pricing policy. For example, an excessively "strict" pricing policy may withdraw the competing suppliers from the market. The paper also considers the possibility of reducing the purchase prices for high-tech products in the long run. The idea is to construct a high-tech product market model that reflects the relationship between the unit purchase price and the number of competing suppliers established in the market in the long run, depending on the unit price offered by the monopsonist customer at the initial time.

A significant number of works on modeling markets of high-tech products were published in foreign economic literature. Despite this fact, few results of practical value (or, at least, of methodological interest) were obtained therein. For example, in [3, 4, 11], strict assumptions on the classes of manufacturer's cost functions and product demand functions were introduced. Often even the number of players is limited (usually 1 or 2 on each side). In the papers [5, 6], the original goal was to optimize the customers' pricing policy in the long-term and forecast the number of suppliers and their capacities. However, the cited authors investigated the application of their results (often qualitative, despite the presence of mathematical models) to antimonopoly policy, focusing on the welfare of consumers and producers (measured by their surpluses). Many researchers directly indicate that the pricing mechanism is not the subject of study and describe it as the "black box."

In the paper [9], the Markov models of bargaining were considered for bilateral oligopoly markets as a primary application. Nevertheless, the main attention was paid to establishing links between firms in network organizations rather than to the processes of pricing, survival, or closing of enterprises in such markets. These processes will be studied below.

2. MODEL FOR DETERMINING EQUILIBRIUM PURCHASE PRICES AND NUMBER OF COMPETING SUPPLIERS

In the paper [7], a model was proposed for estimating the purchase prices for high-tech products in the markets where competing suppliers have only one service channel. This paper considers a similar model, but competing suppliers have flexible production capacities. Let us modify the stochastic bilateral oligopoly model [7] as follows. Assume that N competing suppliers (contractors, manufacturers, etc.) and M potential customers (buyers, including the government, or system integrators of final products, etc.)) operate in a market. The suppliers and customers are supposed homogeneous. Each supplier can simultaneously execute x orders for purchased products of different standard sizes (for example, using homogeneous production lines). After an appropriate reconfiguration, each production line can simultaneously execute only one order. Assume that each customer implements y projects in parallel. Within each of these projects, the need to conclude another contract for the supply of high-tech products occurs in T_{per} years on average. Denote by T_{cntr} the average duration of contract execution. Then $n = N \cdot x$ is the total number of production lines (service channels) in this market, and $m = M \cdot y$ is the total number of parallel projects implemented by the customers. The prices in the bilateral and unilateral monopoly markets are exogenous parameters, and the price in the unilateral monopsony market is the control variable of the model. Let the number m of potential order sources be fixed. Then the number N of the suppliers remaining in the market, as well as the number x of their service channels, can be treated as the model variables and optimized in the following way. Each supplier optimizes its production capacity (the number of service channels) regardless of the other suppliers. Therefore, each supplier can be represented as a multi-channel closed queuing system with the simultaneous execution of orders from several consumers; for details, see the paper [11]. In real networks, the centers of competence operate exactly in such a mode, optimizing their load and saving the available resources.

The equilibrium market condition arising under the competition of suppliers in the high-tech product market will be forecasted in two stages; see formulas (2.1) and (2.2) below.

1) For a fixed unit price of the monopsonists, we optimize the total number of service channels available to an individual supplier by maximizing its total profit:

$$\varPi = x \cdot [\overline{p}(p_{monopsony}; x) \cdot q - AVC \cdot q - FC] \to \max_{x}, \tag{2.1}$$

where $\varPi$ is the total profit of an individual supplier; x is the number of its service channels; $\overline{p}$ is the weighted average unit purchase price of high-tech products; $p_{monopsony}$ is the unit price in the unilateral monopsony market; q is the average annual output under one contract; AVC is the average variable costs; FC is the fixed costs of maintaining one service channel. The solution of this problem yields the optimal production capacity x_{opt} of an individual supplier.

2) We estimate the possible presence of profitable suppliers in the market. For a fixed unit price of the monopsonists and the corresponding optimal production capacity x_{opt}, we find the maximum possible number of suppliers in the market under which the profit of an individual supplier (or service channel) remains positive:

$$N \to \max : \varPi = x_{opt} \cdot [\overline{p}(p_{monopsony}; N \cdot x_{opt}) \cdot q - AVC \cdot q - FC] > 0. \tag{2.2}$$

The solution of this problem yields the maximum possible number $N_{\max}$ of profitable suppliers in the market. Following this approach, we construct the dependence of the weighted average unit purchase price on the monopsonist's unit price.

Therefore, this model allows determining the equilibrium purchase prices established in the market in the long run, the number of competing suppliers, and the optimal capacity of each supplier, depending on the monopsonist's unit price.

Note that this paper considers a static (steady-state) mode of operation of the queuing system. The steady-state mode is achieved at times exceeding those of all system processes (order receipt and execution). Moreover, all conclusions will be valid if the forecasting horizon exceeds the order receipt and execution times.

3. PARAMETRIC CALCULATIONS OF OPTIMAL PURCHASE PRICE OFFERED BY CUSTOMER TO COMPETING SUPPLIERS WITH MULTI-CHANNEL PRODUCTION CAPACITIES

Using an example typical for some branches of the high-tech industry, we calculate the purchase prices for high-tech products and oligopoly surcharges to the cost price due to the market power of competing suppliers. Let the unit product prices in the unilateral and bilateral monopoly markets be $p_{monopoly}$ = 200 monetary units (m.u.) and $p_{bilateral}$ = 150 m.u., respectively.

Example 1. Assume that: the average annual output under one contract is q = 24 units; the unit average variable costs are AVC = 95 m.u.; the unit fixed costs of maintaining one service channel are FC = 120 m.u. These parametres are typical for some branches of the high-tech industry. That is, AFC = 5 m.u. and AC = 100 m.u., but only for an active service channel loaded by one order. Roughly speaking, such a production cost structure is typical for the main subsectors of the foreign aircraft industry; see [1, 2, 10]. The average fixed costs constitute no more than 5% of the total production costs, but only for the enterprises executing orders (and not the idle ones). Consider three average durations of contract execution, T_{cntr} = 2, 5, and 20 years, and two average periods between the orders, T_{per} = 1 and 5 years. We explore the cases of one and several potential sources of orders for high-tech products (m = 1 and m = 2,…, 10, respectively). For each case, the weighted average unit purchase prices for high-tech products calculated depending on the customer's pricing policy are shown in Figure 3.1.

Fig. 3.1. Dependence of weighted average unit purchase price on customer policy (capital-output ratio 5%; order execution rate 0.2; order flow rate 1).

Suppose that the unit price offered by the monopsonists is close to the average variable costs. In this case, the competing service channels cannot survive in the long run: they can only succeed if they periodically receive a higher unit price in the bilateral or unilateral monopoly conditions. At the same time, when the unit purchase price in a competitive supplier environment (i.e., a parameter controlled by the customers with market power) exceeds some threshold allowing the competing service channels to cover the number of potential order sources profitably ($n > m$), the average unit purchase price can sharply drop: in any state of the queuing system there will be free service channels, and the average unit purchase price will coincide with the unit price offered by the customers, $\overline{p} \equiv p_{monopsony}$. Moreover, the average unit purchase price will increase infinitely with the growth of the unit price offered by the customers. Thus, the dependence of the average unit purchase price on the monopsonist's unit price, $\overline{p} = \overline{p}(p_{monopsony})$, may achieve minimum at some price exceeding the minimum possible one in the short run ($p_{monopsony} > AVC$). Even being monopsonists, the customers should assign a high enough unit purchase price for high-tech products to attract the competing suppliers and contractors. In this case, the customers will reduce the purchasing costs in the long run, avoiding the suppliers' monopoly.

Figure 3.1 shows the gain from applying the pricing strategy proposed in this paper, i.e., a decrease in the average unit purchase prices with an increase in the monopsonist's unit price. In all cases, the monopsonist can select such a unit price so that the total production capacity in the market will exceed the number of potential order sources, i.e., in any state of the queuing system, the market will be competitive. Tables 3.1 and 3.2 present some fragments of the calculated data for the model. The green row in these tables corresponds to the monopsonist's optimal unit price and the minimum weighted average unit purchase price.

In this case, compared to the saving-based purchasing policy, the weighted average unit purchase price may decrease by 7–47% for T_{cntr} = 20 years and T_{per} = 5 years; by 11–47% for T_{cntr} = 5 years and T_{per} = 1 year; by 27–48% for T_{cntr} = 20 years and T_{per} = 1 year; up to 45% for T_{cntr} = 2 years and T_{per} = 1 year. For T_{cntr} = 2 years, T_{per} = 1 year, and m = 9, there is no characteristic decrease in the weighted average unit purchase price.

The optimal unit purchase price in the market is defined as the minimum weighted average unit purchase price at which the total production capacity in the market exceeds the number of potential order sources (the market is competitive).

For m varying from 1 to 10, the optimal unit purchase prices are as follows: for T_{cntr} = 20 years and T_{per} = 5 years, 108, 108, 104, 105, 103, 105, 103, 103, 102, and 103 m.u., respectively; for T_{cntr} = 5 years and T_{per} = 1 year, 108, 108, 104, 105, 103, 104, 102, 103, 104, and 103 m.u., respectively; for T_{cntr} = 20 years and T_{per} = 1 year, 106, 106, 106, 103, 102, 103, 103, 103, 104, and 103 m.u., respectively; for T_{cntr} = 2 years and T_{per} = 1 year, 111, 107, 106, 107, 105, 107, 105, 107, 106, and 107 m.u., respectively.

Table 3.1. Fragments of calculated data based on the model (capital-output ratio 5%; order execution rate 0.2; order flow rate 1; the number of potential order sources 1)

m=1				
$p_{monopsony}$	$\bar{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	150	1	1	1
102	150	1	1	1
107	150	1	1	1
108	108	1	2	2
109	109	1	2	2
114	114	1	3	3
120	120	1	4	4
126	126	1	5	5
132	132	1	6	6
138	138	1	7	7
144	144	1	8	8
149	149	1	8	8

Table 3.2. Fragments of calculated data based on the model (capital-output ratio 5%; order execution rate 0.2; order flow rate 1; the number of potential order sources 5)

m=5				
$p_{monopsony}$	$\bar{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	177	3	1	3
101	177	3	1	3
103	103	3	2	6
104	104	3	2	6
106	106	3	3	9
110	110	3	4	12
114	114	3	5	15
117	117	3	6	18
139	139	3	12	36
142	142	3	13	39
149	149	3	14	42

Example 2. Within the data of Example 1, let the annual fixed costs of maintaining one service channel be FC = 600 m.u. Thus, the share of the fixed costs in the cost structure now constitutes almost 21% of the total costs; see Figure 3.2.

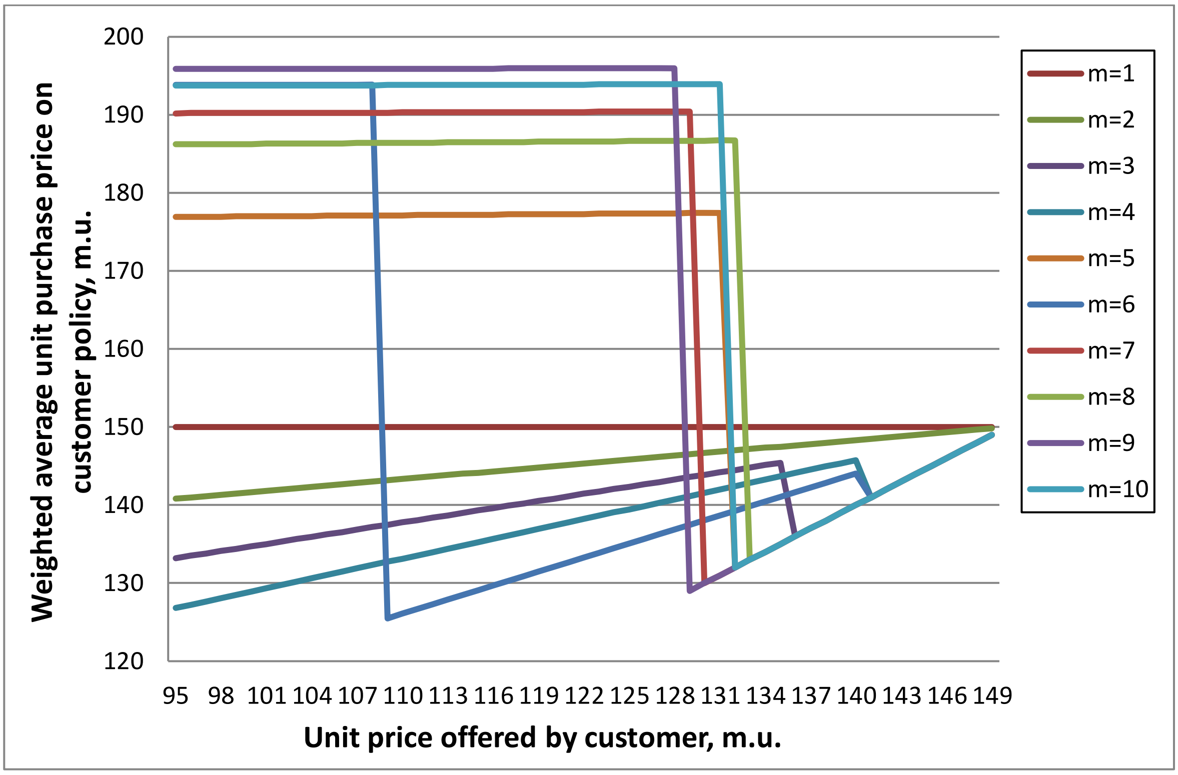

Fig. 3.2. Dependence of weighted average unit purchase price on customer policy (capital-output ratio 20%; order execution rate 0.2; order flow rate 1)

Figure 3.2 demonstrates well the gain from applying the pricing strategy proposed in this paper. In this case, compared to the saving-based purchasing policy, the weighted average unit purchase price may decrease by 34% for T_{cntr} = 20 years and T_{per} = 5 years or T_{per} = 1 year; by 35% for T_{cntr} = 5 years and T_{per} = 1 year; by 33% for T_{cntr} = 2 years and T_{per} = 1 year. Tables 3.3 and 3.4 present some fragments of the calculated data for the model. The green row in these tables corresponds to the monopsonist's optimal unit price and the minimum weighted average unit purchase price.

For T_{cntr} = 20 years and T_{per} = 5 years, or T_{cntr} = 5 years and T_{per} = 1 year, the monopsonist cannot select a unit purchase price so that the total production capacity in the market will exceed the number of potential order sources if m=1 and m=2. In these cases, the total production capacity may even be equal to the number of potential order sources. The same situation is observed for T_{cntr} = 2 years and T_{per} = 1 year if m=1, m=2, m=4, m=6, m=8, and m=10. For example, a single customer always has to interact with a single supplier. In other cases, only the equality between the total number of service channels and the number of potential order sources can be achieved.

A characteristic decrease in the weighted average unit purchase price will not occur for T_{cntr} = 20 years and T_{per} = 5 years if m=1, m=2, and m=3; for T_{cntr} = 5 years and T_{per} = 1 year if m=1,

m=2, m=3, and m=4; for T_{cntr} = 2 years and T_{per} = 1 year if m=1 and m=5; for T_{cntr} = 20 years and T_{per} = 1 year if m=1 and m=2.

For m varying from 3 to 10, the optimal unit purchase prices are as follows: for T_{cntr} = 20 years and T_{per} = 5 years, 137, 142, 133, 142, 131, 135, 130, 133 m.u., respectively; for T_{cntr} = 5 years and T_{per} = 1 year, 136, 141, 132, 141, 130, 133, 129, and 132 m.u., respectively; for T_{cntr} = 20 years and T_{per} = 1 year, 148 m.u. (m = 1, 2, 3) and 135, 127, 131, 133, 135, 131, and 132 m.u. for m varying from 4 to 10, respectively; for T_{cntr} = 2 years and T_{per} = 1 year, 146, 141, 133, 144, and 146 m.u. for m = 3, 5, 6, 7, and 9, respectively.

Table 3.3. Fragments of calculated data based on the model (capital-output ratio 20%; order execution rate 0.2; order flow rate 1; the number of potential order sources 7)

m=7				
$p_{monopsony}$	$\overline{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	190	4	1	4
100	190	4	1	4
105	190	4	1	4
110	190	4	1	4
120	190	4	1	4
125	190	4	1	4
130	130	4	2	8
136	136	4	2	8
140	140	4	2	8
147	147	4	3	12
148	148	4	3	12
149	149	4	3	12

Table 3.4. Fragments of calculated data based on the model (capital-output ratio 20%; order execution rate 0.2; order flow rate 1; the number of potential order sources 9)

m=9				
$p_{monopsony}$	$\overline{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	196	5	1	5
100	196	5	1	5
105	196	5	1	5
110	196	5	1	5
120	196	5	1	5
129	129	5	2	10
144	144	5	2	10
145	145	5	2	10
146	146	5	3	15
147	147	5	3	15
149	149	5	3	15

Example 3. Consider now another example in which the annual fixed costs of maintaining a single service channel are *FC* = 1000 m.u. Compared to the previous scenario, the share of the fixed costs in the cost structure is even higher, reaching 31% of the total costs; see Figure 3.3.

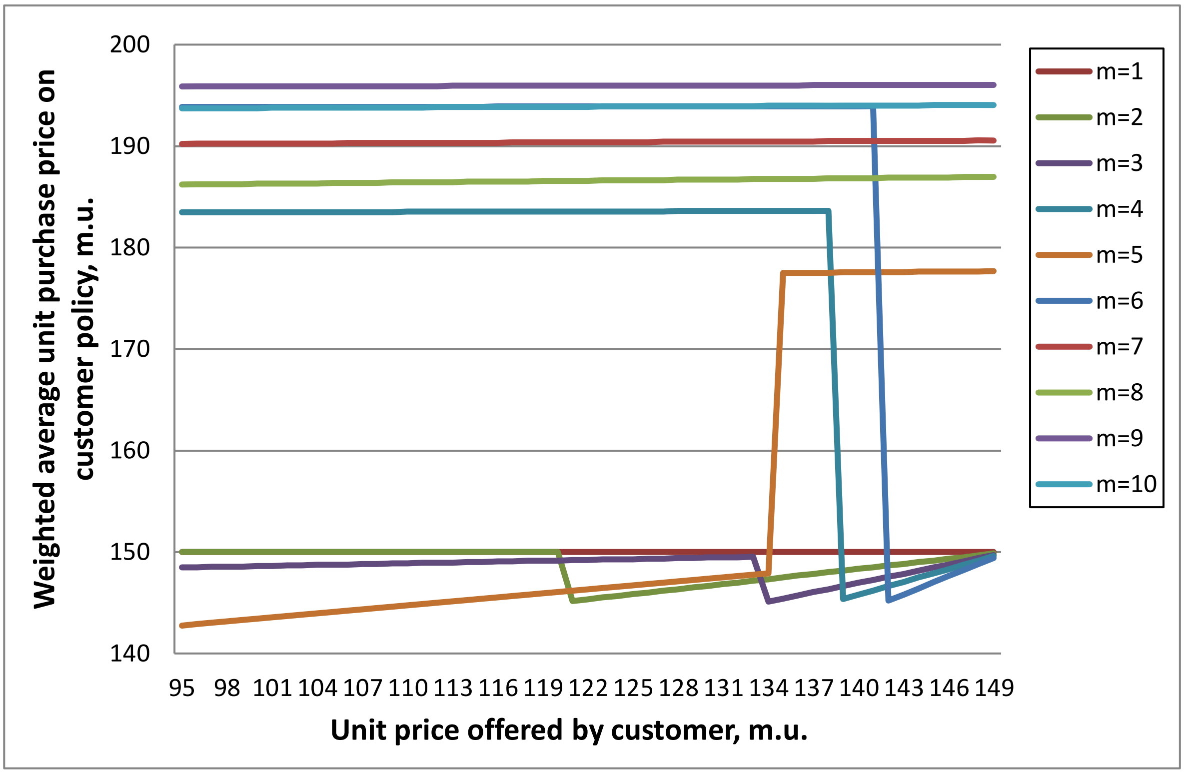

Fig. 3.3. Dependence of weighted average unit purchase price on customer policy (capital-output ratio 30%; order execution rate 0.2; order flow rate 1)

In this case, compared to the saving-based purchasing policy, the weighted average unit purchase price may decrease by 28% for T_{cntr} = 20 years and T_{per} = 5 years; by 23% for T_{cntr} = 20 years and T_{per} = 1 year if m=5; by 25% for T_{cntr} = 5 years and T_{per} = 1 year; by 21% for T_{cntr} = 2 years and T_{per} = 1 year. Tables 3.5 and 3.6 present some fragments of the calculated data for the model. The green row in these tables corresponds to the minimum weighted average unit purchase price; in Table 3.6, it also corresponds to the monopsonist's optimal unit price.

The monopsonist can select a unit purchase price so that the total production capacity in the market will exceed the number of potential order sources only in the case T_{cntr} = 20 years, T_{per} = 1 year and m = 5. The optimal unit purchase price in the market is 148 m.u.

For example, for T_{cntr} = 20 years and T_{per} = 5 years, a single order source always has to interact with a single service channel. For m = 2, 3, 4, 6, and 8, it is possible to achieve the equality between the number of potential order sources and the total capacity in the market. For m = 5, it is possible to attract a maximum of 4 service channels to the industry. For m = 7, 9, and 10, only 4, 5, and 6 service channels, respectively, can survive in the market.

For T_{cntr} = 20 years, T_{per} = 1 year, and m = 1, 2, 3, and 4, only the equality between the number of potential order sources and the total capacity in the market is possible. For m = 6, 7, 8, 9, and 10, only 4, 5, 5, 6, and 7 service channels, respectively, can survive in the market.

For T_{cntr} = 5 years and T_{per} = 1 year, a single order source always has to interact with a single service channel. For m = 2, 3, 4, and 6, it is possible to achieve the equality between the number of potential order sources and the total capacity in the market. For m = 5, a maximum of 4 service channels are possible. For m = 7, 8, 9, and 10, only 4, 5, 5, and 6 service channels, respectively, can survive in the market.

For T_{cntr} = 2 years, T_{per} = 1 year, and m = 1, the monopsonist customer cannot select a unit purchase price so that at least one supplier will profitably operate in the market. In the other cases, the total capacity is smaller than the total number of potential order sources. For example, for m = 2, 3, 9, and 10, only 1, 2, 4, and 5 service channels, respectively, can survive in the market. For m = 4, 5, 6, 7, and 8, a maximum of 3, 4, 4, 6, and 4 service channels, respectively, can be achieved in the market.

A characteristic decrease in the weighted average unit purchase price will not occur with an increase of the monopsonist's unit price for T_{cntr} = 20 years and T_{per} = 5 years if there are 1, 7, 9, and 10 potential order sources in the market; for T_{cntr} = 5 years and T_{per} = 1 year, if m = 1, 5, and 7–10; for T_{cntr} = 2 years and T_{per} = 1 year, if m = 1–3, 6, 9, and 10; for T_{cntr} = 20 years and T_{per} = 1 year, if m = 1–4 and 6–10.

Table 3.5. Fragments of calculated data based on the model (capital-output ratio 30%; order execution rate 0.2; order flow rate 1; the number of potential order sources 6)

m=6				
$p_{monopsony}$	$\overline{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	194	3	1	3
100	194	3	1	3
110	194	3	1	3
120	194	3	1	3
130	194	3	1	3
142	145	3	2	6
144	146	3	2	6
145	147	3	2	6
146	148	3	2	6
147	148	3	2	6
148	149	3	2	6
149	149	3	2	6

Table 3.6. Fragments of calculated data based on the model (capital-output ratio 30%; order execution rate 0.05; order flow rate 1; the number of potential order sources 5)

m=5				
$p_{monopsony}$	$\overline{p}$	x_{opt}	$N_{\max}$	$n = N_{\max} \cdot x_{opt}$
95	193	3	1	3
100	193	3	1	3
105	193	3	1	3
110	193	3	1	3
120	193	3	1	3
129	193	3	1	3
144	193	3	1	3
145	193	3	1	3
147	193	3	1	3

148	148	3	2	6
149	149	3	2	6

4. CONCLUSIONS

This paper has proposed a model for determining the purchase prices for high-tech products in the markets of competing suppliers with flexible production capacity.

As has been established, in some cases, the customer benefits by offering a higher price for high-tech products to ensure the existence of competing suppliers and (or) to reduce the purchase price in the long run.

Under a higher value of the capital-output ratio, the gain from applying the proposed pricing strategy decreases. Compared to the saving-based purchasing policy, the achievable decrease in the weighted average unit purchase price is reduced. For example, under a low value of the capital-output ratio, it is possible to reduce the unit purchase price by 48%; under medium and high values of the capital-output ratio, by 35% and 28%, respectively. In addition, the optimal unit purchase prices for which the market will be competitive in any state increase with the growth of the capital-output ratio. For example, under a low value of the capital-output ratio, the optimal unit purchase price is 103–111 m.u.; under medium and high values of the capital-output ratio, 127–146 m.u. and 148 m.u., respectively.

As a rule, the relative gain from applying the proposed pricing strategy decreases with an increase in the order execution rate or a decrease in the order flow rate. In these cases, as a rule, the optimal unit purchase prices increase and/or the opportunities to attract the competing suppliers to the industry decrease.

Under a low value of the capital-output ratio, the customer always selects a price so that the market in any state will be competitive: there is always a choice from the competing suppliers. Under a medium value of the capital-output ratio, the customer selects the optimal price with a low value of the order execution rate and a high value of the order flow rate; in other cases, as a rule, with a middle or high number of potential order sources. With a high value of the capital-output ratio, the customer finds an optimal price only with a low value of the order execution rate, a high value of the order flow rate, and many potential order sources.

A decrease in the weighted average unit purchase price with an increase in the monopsonist's unit price occurs under a low value of the capital-output ratio. However, if the order execution rate is high, this is possible only under a small or medium number of potential order sources. Under a medium value of the capital-output ratio, a decrease in the unit purchase price occurs for a high value of the order execution rate and a certain number of potential order sources; in other cases, only for a medium or high number of potential order sources. Under a high value of the capital-output ratio, a decrease in the unit purchase price occurs in each case only for a certain number of potential order sources.

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