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**A Taxonomy of Monopolistic Pricing**

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# **A Taxonomy of Monopolistic Pricing\***

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## **ABSTRACT**

Textbooks present the three ‘degrees’ of price discrimination as a sequence of independent pricing methods. These textbook treatments consequently provide inadequate insight as to when a firm might adopt a particular pricing strategy. The paper describes an information-based taxonomy of price discrimination, which can be used to teach monopolistic price discrimination in an integrated way. The pricing strategy adopted by firms is based on the information on consumer demand available to it. The paper proposes a method for ranking profit and efficiency levels under different price discrimination strategies. The information-based taxonomy is compared to the traditional textbook approach.

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\* We would like to thank David Prentice for his helpful comments on an earlier draft. All errors remain our responsibility.

# A Taxonomy of Monopolistic Pricing

## 1. Introduction

Price discrimination is observed in daily life. Students can purchase bus tickets at a discounted rate, once they have provided evidence that they are a student (usually by producing their student cards). They can often buy bundles of bus tickets at a cheaper per unit price than one bus ticket. In these examples the students are paying different prices to other travellers for the same trip on the bus. In explaining such behaviour textbooks usually adopt the taxonomy proposed by Pigou (1920), whereby examples of price discrimination are placed in one of three types (degrees).

A difficulty with the Pigouvian taxonomy used by textbooks is that it treats the types (or degrees) of price discrimination as a sequence of independent pricing methods. In the example of bus tickets, the textbook explanation for the quantity discount is different to that for the student discount. These textbook treatments consequently provide little insight as to when a firm might adopt third degree price discrimination as opposed to second degree price discrimination or when a firm might use a mix of third and second degree price discrimination strategies. Recent literature takes the view that the price discrimination strategy adopted by the firm is associated with the information on consumer demand available to it. To this end, this paper describes an information-based taxonomy of price discrimination, and shows how it can be used to teach monopolistic pricing, including price discrimination, in an integrated way.

Typically textbooks present first, third and sometimes second degree price discrimination, and treat these types of price discrimination as analytically distinct. Indeed the technical treatments are usually incompatible with one another. First-degree price discrimination is necessarily discussed in terms of nonlinear pricing when customers purchase more than one unit. It is common to see an analysis involving two consumers whose demand curve for the good differ. The firm maximises profit (and incidentally social surplus) by charging a tariff to each customer type equal to total benefit for the efficient quantity for that customer type (which occurs where the type's marginal benefit equals marginal cost). Third degree price

discrimination is discussed in the context of linear pricing. Invariably textbooks consider two groups of customers whose market demand curves have different elasticities. The firm sets price to each group at the point where the marginal revenue of the group is equal to marginal cost.

The modern textbook treatment of second-degree price discrimination (e.g. Tirole 1988, and Carlton and Perloff 2004) differs from that identified by Pigou (1920). There is some confusion regarding Pigou's original definition of second-degree price discrimination. Many recent writers include self-selection via non-linear pricing as a form of price discrimination. Stole (2007) notes that Pigou (1920) did not consider second degree price discrimination as a selection mechanism, but rather thought of it as an approximation of first degree using a step function below the consumer's demand curve. As such, Pigou regarded both first and second-degree price discrimination as "scarcely ever practicable" and 'of academic interest only'.

The modern treatment of second-degree price discrimination, beginning with Spence (1977) and Maskin and Riley (1984), utilizes modern advances in information economics to explicitly model the information asymmetry between a firm and its customer. Whereas first-degree price discrimination is used when each customer's type is common knowledge, second-degree price discrimination is used when a customer's type is private information (known only to the customer herself). Under second-degree price discrimination nonlinear pricing schedules are used to provide customers with an incentive to self identify. The modern textbook treatment of second-degree price discrimination usually follows this approach. These treatments consider two customer types, one of whose demand curve lies uniformly above the other. Non-linear prices are used to provide an incentive for customers to reveal their types. Examples of such non-linear pricing are abundant, so Pigou was incorrect in asserting that second-degree price discrimination is 'of academic interest only'.

Teaching the three types of price discrimination using the (inconsistent) Pigouvian taxonomy can be confusing. In contrast, by systematically modifying the information available to the firm regarding the distribution of customer demands, we identify the optimal (discriminatory) pricing strategy available to firms. We thus provide an integrated treatment of the incentives for price discrimination and propose an approach that allows students to view the firm's profit level as a function of the optimal mix of second and third degree price discrimination strategies.

Observation of firms indicates that in many cases they do not use either second or third but approach their pricing using a mix of the two types of price discrimination. This is the case for the bus company discussed above. Similarly cinemas offer both student discounts and discounts for quantity. Accommodation providers offer a corporate and leisure rate, as well as discounts for extended stays. The framework we propose readily models this behaviour. We will use non-linear pricing strategies to demonstrate this approach. We will show that a firm has an incentive to use non-linear pricing rather than linear pricing where possible.

Our analysis proceeds as follows. First we outline the assumptions regarding consumer demand. Then we identify the optimal non-linear pricing strategy given the information structure. Then the profitability and efficiency of each pricing strategy is ranked. This ranking is related to the information structure. Finally the analysis using nonlinear pricing is related to the traditional analysis of (third degree) price discrimination using linear pricing.

## 2. Customer Demand

We start with the assumption that the firm, which is a monopoly, is aware of the distribution of customers' demand curves (and thus can calculate market demand), but it may not be able to costlessly associate a demand curve with a particular customer. It is also useful to restrict consideration to those cases in which demand curves of different customer types do not cross. This provides an unambiguous ranking of customers in terms of their willingness to pay, thus a particular customer types can be identified as having a higher or lower demand than other customer types. This condition is known variously as 'uniform ordering', the 'sorting condition', the 'single crossing condition' or the 'Spence-Mirrlees' condition'. The same demand curves can then be used throughout the analysis of first, second and third degree price discrimination thereby providing students with a framework that is analytically self-contained.

We further restrict attention to the case in which there are three customer types. Discussions of price discrimination in the textbooks generally consider only two customer types. However, to consider the examples of price discrimination discussed in the introduction, and to develop a conceptually encompassing information-based taxonomy, requires a minimum of three customer types. The analysis could be extended to more customer types but this yields little additional economic insight. Thus for ease of presentation we restrict consideration to three customer types.

Figure 1 illustrates the condition for three types of customers: Customers H (high demand), M (medium demand) and L (low demand). We will use the same demand curves throughout the analysis in the following section. Note that under this condition type H customers have a higher total valuation ( $H^0 > M^0 > L^0$ ) and higher marginal valuation ( $P_H^0 > P_M^0 > P_L^0$ ) of any level of provision of the good.

*Insert Figure 1*

### 3. Price Discrimination with Nonlinear Pricing

The pricing strategy adopted by the firm depends on how readily it can identify customers as belonging to the different types. Below we consider the cases in which (i) the firm can costlessly identify each customer's type, (ii) can costlessly identify only one type of customer, (iii) cannot identify any customer's type. In order to conduct price discrimination it is necessary that the firm can prevent resale. We will also assume for simplicity that marginal cost for the firm is equal to zero.

#### 3.1 All Customer Types Costlessly Identified

We will start by considering the case where a given customer's type is common knowledge, and thus firms can costlessly identify and separate the three customer types. This corresponds to first-degree price discrimination in the textbooks. The firm can capture all the consumer surplus of each customer type by offering each customer a block tariff (or equivalently a two-part tariff of a lump sum fee and no charge per unit).

The optimal pricing structure in this case is shown in Figure 1. Type L customers are offered schedule  $\langle q_L^*, L^1 \rangle$ , which consists of a bundle of  $q_L^*$  units for tariff equal to  $L^1$ . This schedule leaves the consumer with zero consumer surplus, so the customer is indifferent between purchasing the bundle or not purchasing it. For ease of analysis assume that the customer purchases the bundle when indifferent. Similarly type M customers are offered the schedule  $\langle q_M^*, M^1 \rangle$  where  $M^1 = L^1 + \Delta M^1$  and Type H are offered the schedule  $\langle q_H^*, H^1 \rangle$  where  $H^1 = M^1 + \Delta H^1$ . The number of Type H customers is  $N_H$ , the number of Type M customers is  $N_M$  and the number of Type L customers is  $N_L$ . Profit is equal to:

$$\Pi^1 = N_L L^1 + N_M M^1 + N_H H^1$$

Note that each customer purchases the efficient quantity.

### 3.2 One Customer Type Costlessly Identified

Next assume the firm can costlessly identify (and thus separate) Type L customers. However it cannot costlessly distinguish between Type M customers and Type H customers. The profit maximising pricing strategy requires the firm to separate customers according to the freely available information. In particular each identifiable groups of customers potentially contains within it customers with heterogenous demands e.g. Type M and Type H.

The firm has to set schedule that ensures Type M and Type H customers self select the appropriate bundle. Figure 2 shows how the nonlinear pricing can be used by the firm to profitably separate the type M and type H customers.

*Insert Figure 2*

The firm offers two schedules  $\langle q_M^3, M^3 \rangle$  and  $\langle q_H^3, H^3 \rangle$ . The former schedule is directed at type M customers and the latter type H customers. It is profit maximising for the firm to extract the entire consumer surplus from type M customers. Self-selection requires that the type H customers not purchase the schedule  $\langle q_M^3, M^3 \rangle$ . This means that the high demand customers must be guaranteed a consumer surplus  $V_H^3$ . The maximum consumer surplus the firm can extract from type H customers given this self-selection constraint occurs when  $q_H^3 = q_H^*$  and  $H^3 = H^1 - V_H^3$ .

The firm's problem is then to choose the profit maximising level of  $q_M^3$ . Note that as the firm reduces  $q_M^3$  by one unit the revenue from the tariff paid by type M customers reduces by  $N_M P_M^3$ , as  $P_M^3$  is the marginal valuation of type M customers. At the same time the tariff paid by type H customers can be increased by  $N_H (P_H^3 - P_M^3)$  and still satisfy self selection. The profit maximising level of  $q_M^3$  satisfies  $N_M P_M^3 = N_H (P_H^3 - P_M^3)$ . Firm profit is thus given by:

$$\Pi^3 = N_L L^1 + N_M M^3 + N_H (H^1 - V_H^3)$$

where  $M^3 < H^1 - V_H^3$ . The deadweight loss is given by  $N_M (M^1 - M^3)$ .



Note that if  $N_M P_M^3 < N_H (P_H^3 - P_M^3)$  for all  $q$ , then it is profit maximising to set  $q_M^3 = 0$ . This can happen in two ways:

- (i) the ratio of  $P_H^3$  to  $P_M^3$  may be sufficiently high
- (ii) the ratio of  $N_H$  to  $N_M$  may be sufficiently high.

In this case the firm offers only one schedule to type M and H customers:  $\langle q_H^*, H^1 \rangle$ . This bundle is purchased only by type H customers. If, on the other hand,  $N_M P_M^3 > N_H (P_H^3 - P_M^3)$  for  $q=0$  it must be the case that  $q_M^3 > 0$ . In this case the firm offers two schedules as described above.

Two variants of the information structure assumed above can be readily analysed:

- (i) the firm can costlessly separate type M customers from type L and type H customers, but cannot distinguish between type L and type H customers and
- (ii) the firm can costlessly separate type H from type L and type M customers, but cannot distinguish between Type L and Type M customers. The analysis of these information structures is analogous to the analysis above.

The methodology used in this subsection can be used when the firm has incomplete information on customer types. In these cases the firm maximises profit by firstly using costlessly available information to separate its customers into groups and then further separating these groups into sub-groups of uniform type using the nonlinear pricing schedules as a screening method. Within the groups the customers with the highest demand receive a positive consumer surplus and lower demand customers buy a bundle with inefficient quantity. By offering the lower demand customers an inefficient quantity the lower demand bundles becomes less of a substitute for the highest demand bundle.

The information available to firms in the case considered in this subsection corresponds to Pigouvian third degree price discrimination to the extent that the firm observes groups and within these groups there may be a number of different customer types. In this example the two groups consist of (i) Type L only and (ii) both Type M and Type H customers. However it differs from Pigouvian third degree price discrimination in that screening methods are used

to separate customers within the group.<sup>1</sup> This difference allows the pricing strategies described in the introduction to be explained.

### 3.3 No Customer Types Costlessly Identified

Finally consider the case in which the firm cannot costlessly identify and separate any of the three customer types. This case is sometimes called ‘second degree price discrimination’ in the modern literature. In this case the firm does not have the option of using exogenously provided information (such as a student card or geographical location) to separate customers, but must devise a pricing strategy that identifies a customer type through self-selection. The optimal pricing strategy does this by using pricing schedules in the same way that it separated type M and Type H customers in Section 3.2.

The determination of the optimal pricing structure is shown in Figure 3.

*Insert Figure 3*

The firm offers three schedules  $\langle q_L^2, L^2 \rangle$ ,  $\langle q_M^2, M^2 \rangle$  and  $\langle q_H^2, H^2 \rangle$ , directed at type L, type M and type H customers respectively. It is profit maximising for the firm to extract the entire consumer surplus from type L customers. Self-selection requires that the type M (and H) customers not purchase the schedule  $\langle q_L^2, L^2 \rangle$ . This means that the medium demand customers must be guaranteed a consumer surplus  $V_M^2$ . The profit maximising level of  $q_L^2$  satisfies  $N_L P_L^2 = N_M (P_M^2 - P_L^2)$ . At this point the revenue lost by reducing  $q_L^2$  from type L customers ( $N_L P_L^2$ ) is just offset by the gain in revenue from type M customers ( $N_M (P_M^2 - P_L^2)$ ).

Self-selection requires that type H customers do not purchase the schedule  $\langle q_M^2, M^2 \rangle$ . This requires that type H customers be guaranteed a consumer surplus of  $V_H^2$ . The profit maximising level of  $q_M^2$  satisfies  $N_M P_M^2 = N_H (P_H^2 - P_M^2)$ . At this point the revenue lost by reducing  $q_M^2$  from type M customers ( $N_M P_M^2$ ) is just offset by the gain in revenue from type H

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<sup>1</sup> Note that textbook treatments of third degree price discrimination also assume the firm sets a linear price (rather than non-linear price) to each group because they have insufficient information to further separate customers within the groups. This issues is explored further in section 4.

customers ( $N_H(P_H^2 - P_M^2)$ ). Hence  $q_M^2 = q_M^3$  and  $V_H^2 = V_M^2 + V_H^3$ . Note that if type H customers do not purchase  $\langle q_M^2, M^2 \rangle$ , they would not purchase  $\langle q_L^2, L^2 \rangle$  as it provides a lower consumer surplus.

As in the analysis in the previous section, it is optimal for the firm to set  $q_H^2 = q_H^*$  and to set a fee,  $H^2 = H^1 - V_H^2$ , which is just low enough to deter type H customers from switching to other bundles.

In this case Type L customers buy an inefficient quantity and keep no consumer surplus, Type M customers buy an inefficient quantity and retain some consumer surplus and Type H customers buy an efficient quantity and retain some consumer surplus. Profit is now:

$$\Pi^2 = N_L L^2 + N_M(M^3 - V_M^2) + N_H(H^1 - V_M^2 - V_H^3)$$

Type H customers buy the efficient quantity  $q_H^*$ , Type M customers buy the inefficient quantity  $q_M^2$  and Type L customers buy the inefficient quantity,  $q_L^2$ . The deadweight loss is given by  $N_M(M^1 - M^3) + N_L(L^1 - L^2)$ .

The above analysis was based on the assumption that  $q_M^2 > q_L^2$  where  $q_M^2$  satisfies  $N_M P_M^2 = N_H(P_H^2 - P_M^2)$  and  $q_L^2$  satisfies  $N_L P_L^2 = N_M(P_M^2 - P_L^2)$ . Note that it is possible that these expressions yield values of  $q_M^2$  and  $q_L^2$  such that  $q_M^2 < q_L^2$ . This would be possible if  $N_M$  is relatively small compared with  $N_L$  and  $N_H$ . Clearly this outcome is not consistent with self-selection. In this case ‘bunching’ occurs. There is no separate bundle offered to type M, and both type L and type M customers purchase  $\langle q_L^2, L^2 \rangle$ . In this case  $q_L^2$  is determined by  $(N_L + N_M)P_L^2 = N_H(P_H^2 - P_M^2)$ .

### 3.4 Profit and Efficiency Ranking with Nonlinear Pricing

Since profit varies with the level of information that a firm has about its customers we can now show how to rank profit levels using our information-based taxonomy. The firm makes the maximum possible profit when it can costlessly identify and separate each customer and

offer them a non-linear price that captures their entire consumer surplus. Specifically profit is:

$$\Pi^1 = N_L L^1 + N_M M^1 + N_H H^1$$

Profit is lower than this maximum when only one customer type rather than all customer types can be costlessly identified and separated. If only type L customers can be costlessly identified and separated profit is lower than  $\Pi^1$  because (i) there is a lower fee paid by type M customer because they purchase only  $q_M^3$  (fee  $M^3$ ) rather than  $q_M^*$  (fee  $M^1$ ) and (ii) Type H pay a lower fee of  $H^1 - V_H^3$  rather than  $H^1$ . Mathematically the difference in profit is:

$$\Pi^1 - \Pi^3 = N_M(M^1 - M^3) + N_H V_H^3$$

The difference in profit is the information cost of separating type M customers. The deadweight loss increases by  $N_M(M^1 - M^3)$ .

Profit is even lower when no customer types rather than one customer type can be costlessly identified and separated for three reasons: (i) there is a lower fee paid by type L customer because they purchase only  $q_L^2$  (fee  $L^2$ ) rather than  $q_L^*$  (fee  $L^1$ ) (ii) there is a lower fee paid by type M customers as they pay a fee of  $M^3 - V_M^2$  rather than  $M^3$  and (iii) Type H pay a lower fee of  $H^1 - V_M^2 - V_H^3$  rather than  $H^1 - V_H^3$ . Mathematically the difference in profit is:

$$\Pi^3 - \Pi^2 = N_L(L^1 - L^2) + N_M V_M^2 + N_H V_M^2$$

The difference in profit is the information cost of identifying and separating type L customers. The deadweight loss increases by  $N_L(L^1 - L^2)$

In summary, the less capable is the firm to identify a customer's type (and the more it must rely on self selection), the lower is its profit. Thus the information on customer type can be viewed as a valuable commodity. The more the firm must rely on pricing strategies to reveal a customers type the greater is the deadweight loss.

## 4. Price Discrimination with Linear Prices

Why do firms not offer different schedules to every single customer where there are large numbers of customers with different willingness to pay? It has been shown that the firm maximises profit using the information costlessly available to them or failing that, use non-linear pricing strategies to separate customers so the question should be addressed. The answer is often that in reality the firm cannot use such nonlinear pricing strategies because there are a great many customer types (a wide dispersion of customer demand) and the good can be resold. If the firm cannot prevent resale it must offer a linear price (i.e. a common price per unit) to all customers in order to prevent arbitrage. If the firm did attempt to offer separate schedules to different customer types only the schedule with the lowest price would sell. This price would become the market price. Thus, when the firm cannot prevent resale, we can think of the firm as setting a linear price.

Third degree price discrimination under the Pigouvian Taxonomy occurs when there is both linear pricing and exogenous information as to a customer's type (or group which may consist of many different types). We now relate this type of price discrimination, which is ubiquitous in textbook treatments, to the analysis presented above.

Figure 4 shows textbook (Pigouvian) third degree price discrimination cast in a manner that facilitates comparison with the above analysis. Assume two customer types (the minimum number of types needed to consider the implications), which are labelled M and H. Suppose the firm is constrained to set linear prices.<sup>2</sup> If the firm cannot identify a particular customer's types it must set a common linear price. This is the case of a simple monopoly. The profit maximising, common linear price is shown as  $P^C$ , and the firm maximum profit when the firm cannot identify customer type is thus:

$$\Pi^C = N_M(M^B+M^D) + N_H(H^D+H^E)$$

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<sup>2</sup>. Note that the firm would prefer to use a non-linear price rather than a linear price. This is demonstrated by showing that the firm can increase profit by switching to a non-linear price from a linear price. If the firm could prevent resale (and thus profitably conduct non-linear pricing), it could sell a bundle consisting of  $q_M^C$  to type M customers for a fee of  $M^A+M^B+M^D$ , and sell a bundle of  $q_H^C$  to type H customers for a fee of  $M^A+H^D+H^E$ . This strategy increases the profit per customer by  $M^A$  and additionally satisfies self-selection. Hence using non-linear pricing increases profit relative to linear pricing. Of course the firm can maximise profits by adopting the pricing described in section 3.2 (figure 2). We thus assume that the firm is exogenously forced to set a linear price so that we can compare textbook treatments of third degree price discrimination with the above analysis.

The deadweight loss is:

$$N_M(M^C + M^E + M^F) + N_H H^F$$

Now consider the case in which the firm can costlessly identify customers by their type. This is the case of third degree price discrimination in the Pigouvian taxonomy. The usual textbook examples of student discount on cinema tickets and geographical separation applies to this requirement. The linear price  $P_M^T$  is charged to type M customers, who purchase quantity  $q_M^T$ , and the linear price  $P_H^T$  is charged to type H customers, who purchase quantity  $q_H^T$ . The firm's profit is:

$$\Pi^T = N_M(M^D + M^E) + N_H(H^B + H^D)$$

The deadweight loss is:  $N_M M^F + N_H(H^C + H^E + H^F)$

The impact of the move from common linear pricing to third degree (linear) price discrimination changes profit by:

$$\Delta\Pi = N_M(M^E - M^B) + N_H(H^B - H^E)$$

as type H has inelastic demand and type M has elastic demand  $\Delta\Pi > 0$ . Thus the firm is able to utilise the information identifying customer type to increase its profit. This result is consistent with the analysis above.

However, in contrast to the above analysis, deadweight loss does not reduce as firms are provided with additional information. Specifically, if the firm moves from common linear pricing to third degree (linear) price discrimination the deadweight loss increases by:

$$N_H(H^C + H^E) - N_M(M^C + M^E)$$

This expression is negative when demand curves are linear and output is unchanged but may not be negative in other cases. (Robinson 1933) showed that the movement toward third

degree discriminating prices alters the distribution of output but does not change total output when demand curves are linear. (Schmalensee 1981) showed that deadweight loss increases unless output increases. Thus, when demand curves are linear, the implementation of third degree price discrimination increases deadweight loss. This is apparent from figure 4 once it is realised that with linear demand curves  $N_M(q_M^T - q_M^C)$  must equal  $N_H(q_H^C - q_H^T)$ .

Thus, when output does not increase, the provision of information on customer type that allows the firm to implement third degree price discrimination lowers welfare. This conclusion, implicit in textbook treatments, is the opposite of the result presented in section 3.4. The source of the divergence in the conclusion is due to the use (by the Pigouvian Taxonomy) of linear pricing rather than nonlinear pricing. This results in the firm reducing output to the type H customers in an attempt to capture their consumer surplus. The output supplied to type M customer however increases. This result contrasts to that obtained in section 3.4 for non-linear pricing, where output supplied to type M customers decreases due to implementation of price discrimination.

Thus the conclusions derived from the textbook analysis of (Pigouvian) third degree price discrimination follows from the joint assumptions of linear pricing and exogenous information on customer types (groups). The ability to set differing linear prices to different groups can be justified by assuming while there may be resale within a group, it cannot occur between them. This may be a reasonable assumption in many of the cases discussed in textbook treatments, e.g. geographic separation. However the requirements for this, and other, forms of price discrimination to be profit maximising should be made clear to students. Our treatment ensures this occurs.

## 5. Conclusions

When a market consists of more than one customer type a firm can maximise its profits by charging different types different prices. Thus information on customer types is valuable to firms. When it is common knowledge the firm benefits by using it. However a given customer's type is invariably private information. In these cases non-linear pricing schedules can be used to provide customers with an incentive to reveal their type. However extracting this information comes at a cost to the firm: profit is lower than would be the case if customers' types were common information. In addition the optimal screening method distorts the quantity available to low demand customers and thus generates a deadweight loss.

We have shown how the theory of price discrimination can be developed using an information-based taxonomy. This approach allows for a more coherent understanding of the different strategies adopted by firms. It emphasises that firms use price discrimination strategies as a means of maximising profit given the particular information constraints they face. This approach enables a straightforward explanation of the pricing strategies used by firms in many common real world examples.



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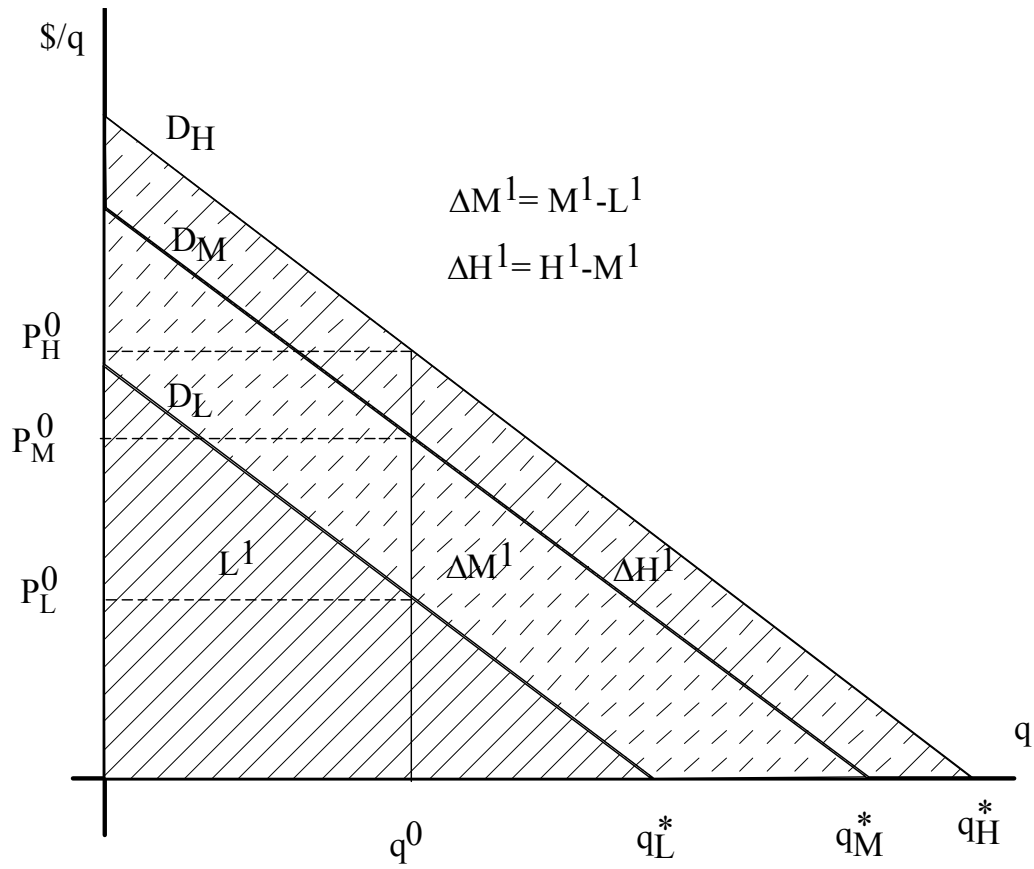


Figure 1: Demand curves satisfying uniform ordering and tariffs under first degree price discrimination.

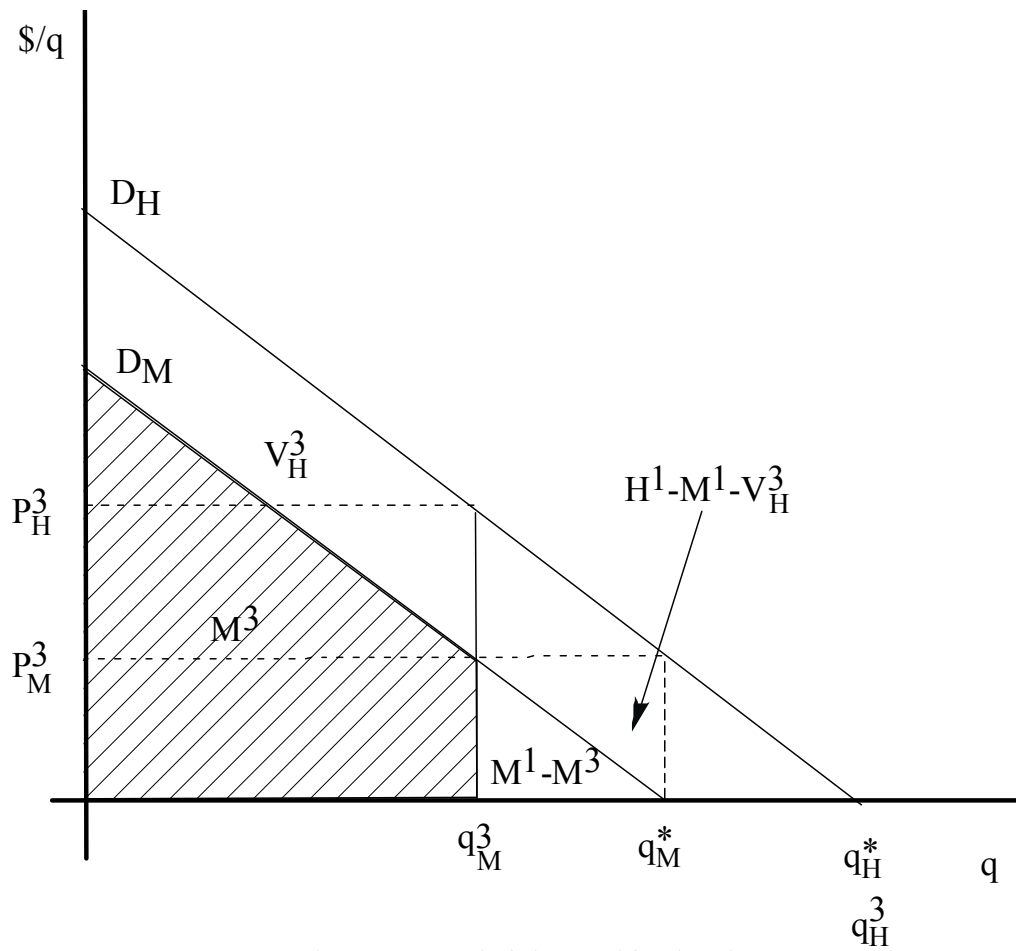


Figure 2: Satisfying self selection.

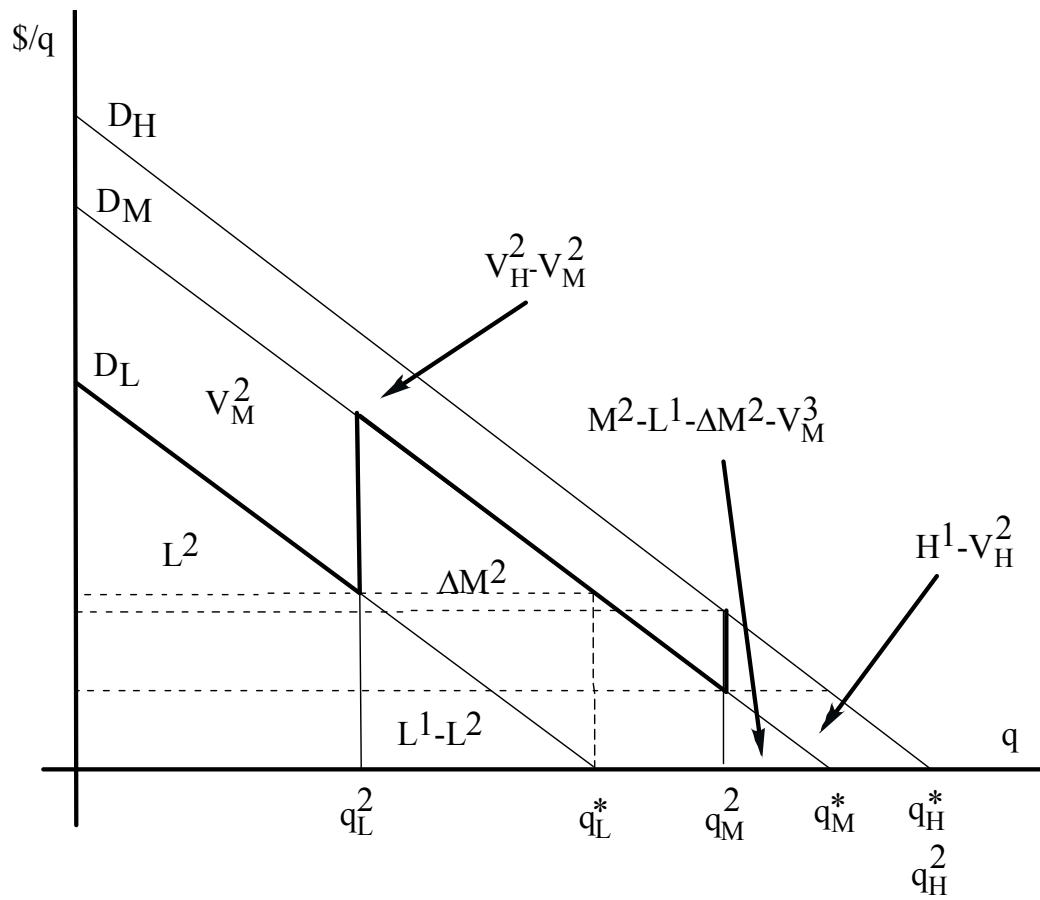


Figure 3: Equilibrium with no exogenous signal.

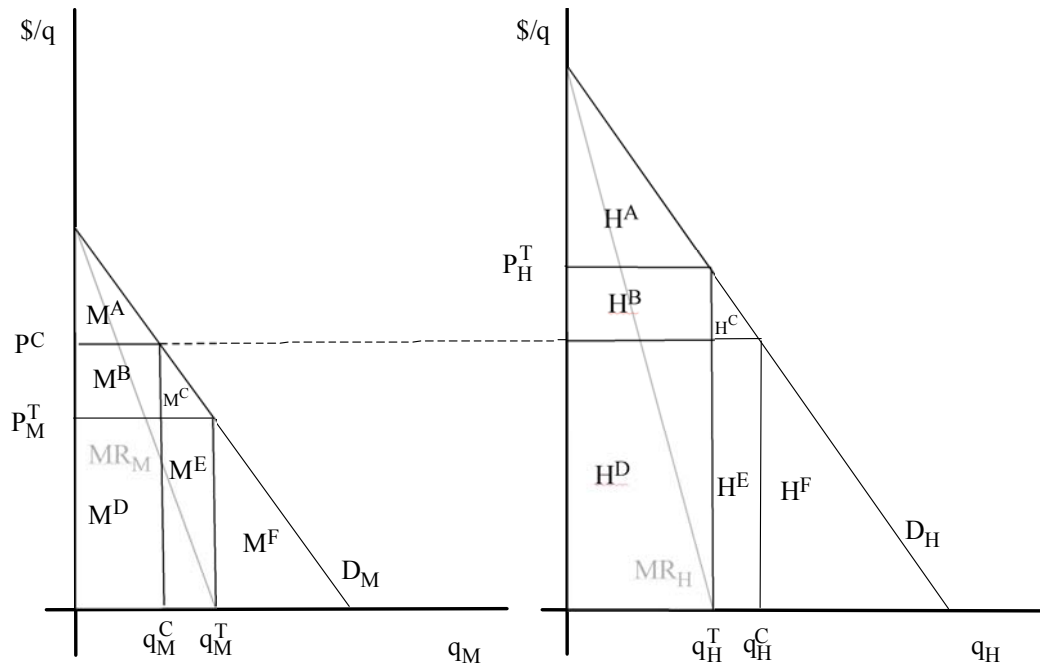


Figure 4: Linear Pricing.

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