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Sunk Costs, Commitment, and Strategy

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Abstract

Commitment is a necessary prerequisite for gaining sustainable competitive advantage. By the way of commitment a firm is able to establish mobility barriers for capital bound in specific assets and to protect thereby supernormal profits against competition by entry barriers. The main underlying mechanism creating commitment is the irreversibility of decisions. Irreversibility not only can give a sustainable competitive advantage but is also a necessary condition for the existence of risk. Even under uncertainty there is no risk if any decision can be completely and costlessly reversed at any time. In that case, strategy and planning for the future are not necessary at all. This reversibility condition is, of course, never completely fulfilled, alone taking into account the passing of time between two points of decision. Commitment is at the heart of competitive advantage and risk; both concepts are of outstanding importance for any firm. The aim of the paper is to analyse potential trade offs between the advantages and disadvantages of commitment and to give an overview of the factors that influence the optimal timing and extent of irreversible investment. The analysis is based upon the concept of sunk costs. Sunk costs measure the irreversibility of investment and constitute an important link between management accounting and strategy.

Keywords: sunk costs, commitment, irreversible investment, competitive strategy, risk, real options

JEL-Classification: L13, M40

1. Elements of Commitment

In many industries specific and irreversible investment is of increasing significance. R&D investment in the chemical, pharmaceutical and bio-technological industry may serve as a vivid example. The building of networks, as in the telecommunications industry, asks for high specific investment. The market structure in most of these industries is neither a perfect market nor a monopoly but an oligopolistic market structure with strategic interaction. Therefore it is of crucial importance to understand the effects of commitment by irreversible investment on a firm and its competitors in these markets.

The first step, necessary in order to analyze these effects is working out a precise definition of commitment. A commitment always consists of three elements (see fig. 1):

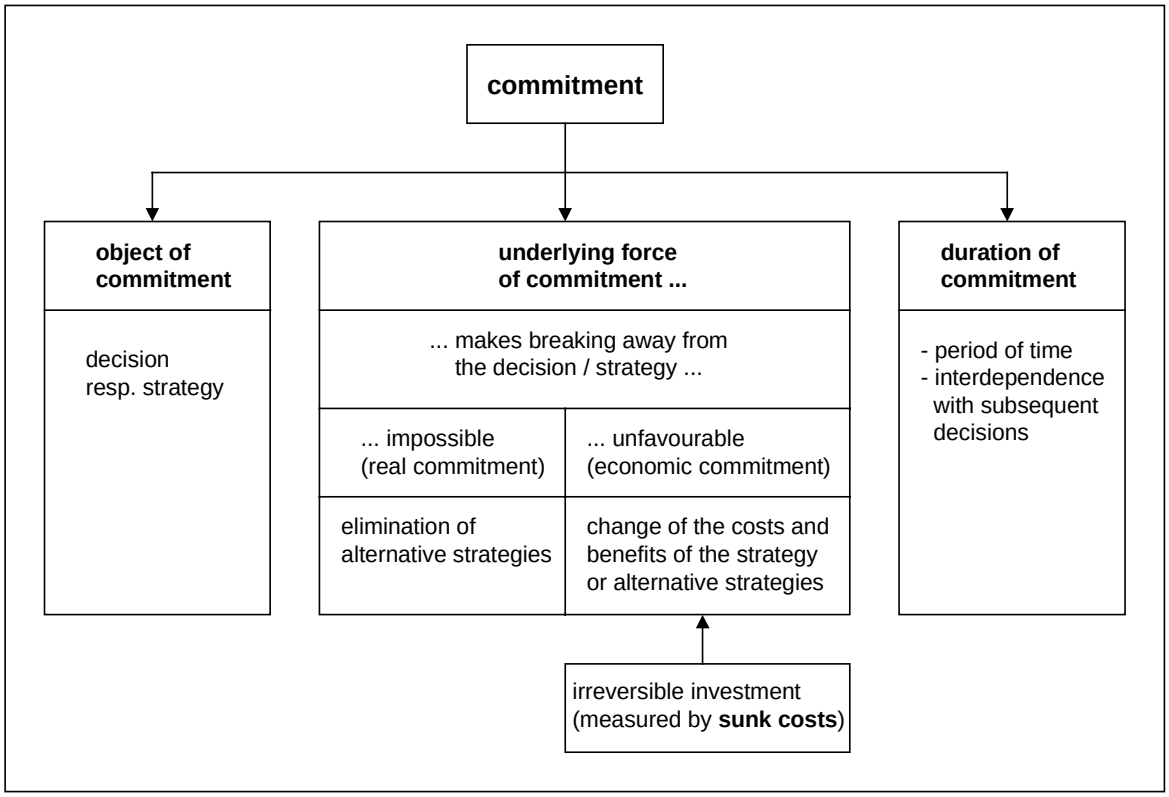

Fig. 1: Elements of commitment

(1) An *object* to which the commitment refers: In a decision theoretic perspective this object is a decision or a strategy.

(2) An underlying *force* of commitment: Commitment means that it is impossible or unfavourable to deviate from a planned course of action. Depending on whether it is literally impossible or just unfavorable as to the subjective goals of the decision maker to change the course of action we can differentiate between real commitment and economic commitment.[1] The fact of being or not being commited economically to a certain strategy depends on if the costs or the benefits of breaking away from the strategy are higher.[2] A real commitment is tantamount to an economic commitment with infinitely high costs of breaking away from a strategy. A real commitment eliminates alternative strategies whereas an economic commitment changes the cash flows of the strategy commited to or of the alternative strategies. A commitment to a certain strategy on one side can be established by implementing the strategy itself and by investing irreversibly resources or on the other side by accompanying actions that increase the costs or decrease the benefits of breaking away from the decision. Irreversibility of a decision means that the effects of

[1] This differentiation already has been made by POTT (1991), pp. 13ff.

[2] See also TIROLE (1988), p. 308.

the decision cannot be completely reversed. Empirically every decision is at least partially irreversible because the passing of time cannot be turned back. In section 2 it is shown how the degree of irreversibility of a decision can be measured by the sunkness of costs.

(3) The *duration* of a commitment: The period of time a commitment persists in depends on how costs and benefits of breaking away from a strategy evolve over time. Two subcases can be differentiated: Either costs and benefits change with goals unchanged or the goals change themselves. In consequence the existence of commitment cannot be analyzed without knowing the individual goals of the decision maker. Furthermore commitment is only relevant if there are interdependences with subsequent decisions.[3] A commitment changes either the alternatives of subsequent decisions or the costs and benefits attainable by those alternatives.

The rest of the paper is organized as follows: In section 2 it is shown how sunk costs are derived in a decision theoretic perspective from past and potential payments of the firm. The degree of sunkness is related to the difference between the acquisition price and the liquidation price of assets the firm invests in for its competitive strategy. An overview of the causes for differences between the two prices is given. In addition the decision irrelevance of sunk costs is shown. The irrelevance of sunk costs leads to an asymmetry between the firm and its competitors. The firm enjoys a cost advantage for the irreversible investment and the corresponding competitive strategy. In section 3 a brief and systematic overview of the competitive advantages is given that can be attained by strategic commitment prior to product market competition in a duopoly game. It is demonstrated that sunk costs (not fixed costs) are the relevant measure for the shift of reaction curves by an irreversible investment. In accordance with the relevant literature distinctions are made between

- product markets where the actions of the duopolists are strategic substitutes (falling reaction curves) and markets where the actions are strategic complements (rising reaction curves),
- commitments that result in an aggressive reaction and commitments that result in a defensive reaction of the firm in the product market and
- strategies to push the competitor out of the market as well as strategies to share the market.

Alongside this, it is shown that the intensively discussed simultaneous attainability of cost advantages and differentiation advantages reaches support from the concept of commitment to specific resources. Section 4 contrasts the competitive advantages that can be gained by commitment to the potential loss of valuable flexibility. Based on the real options approach the conditions under which commitment means foregoing a valuable option to defer investment and the underlying value drivers are identified. Section 5 concludes with some implications for the management of investment and management accounting.

[3] See GHEMAWAT (1991), p. XI; BESANKO/DRANOVE/SHANLEY (1996), p. 319.

2. Irrelevance of Sunk Costs

Figure 2 illustrates how the concept of sunk costs can be derived from past and potential payments of a firm at two different moments of decision.[4] t=0 is the moment immediately before the firm invests money in real assets, t=1 is any moment later at which the sunkness of the investment is measured. In t=0 the firm has disposal of resources in money. Here the firm can choose one of the two following decision alternatives. On one hand it can start a project and invest the cash outflow CO_0 in real assets to get the expected cash flows of the project (CI = cash inflow; L = liquidation payment; D = time horizon) or on the ohter hand it can not invest and keep the money. For simplicity the discount factor is assumed to zero. In t=0 the firm decides to invest in real assets. In t=1 the investment process is assumed to be completed.

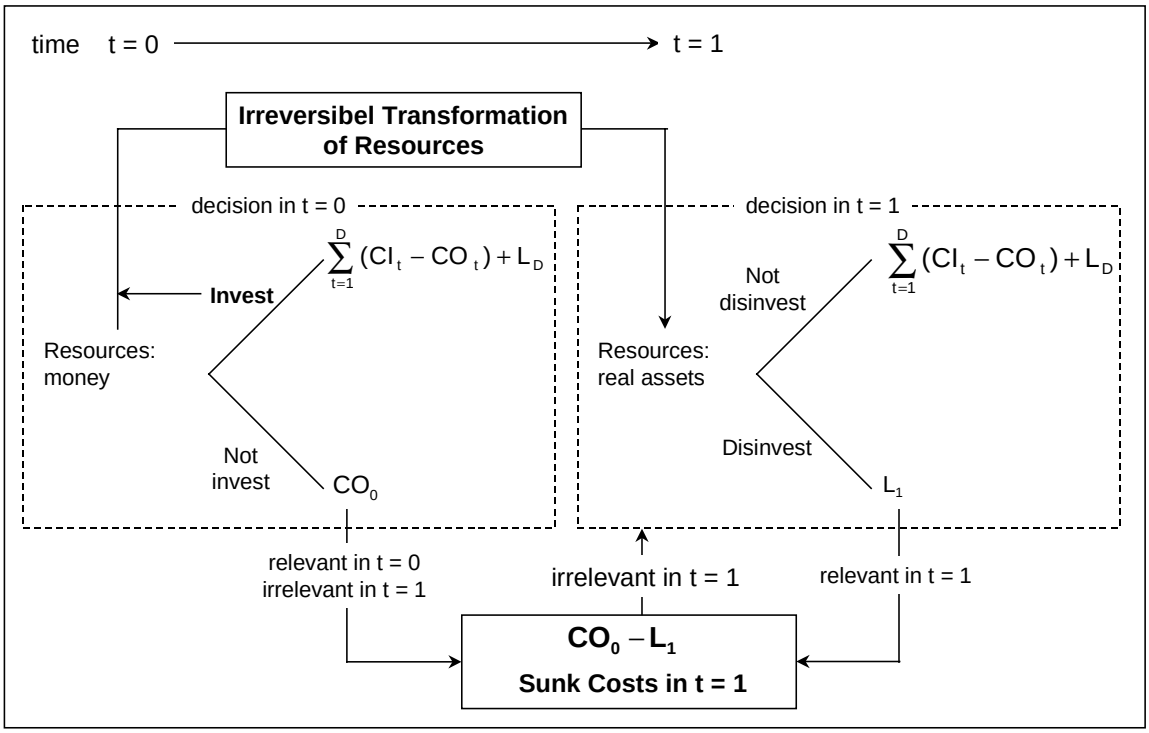

Fig. 2: Sunk costs and payments

The investment process induces a more or less irreversible transformation of resources: In t=1 the firm has again two decision alternatives. It can continue the project and earn the expected cash flows or it can liquidate the procured capacity that means liquidate the real assets on the second-hand market and take the payment L_1. If the decision in t=0 has been made under certainty the advantageousness of the investment did not change and the firm will continue the project. Under uncertainty the advantageousness of the investment may have changed due to new information received between t=0 and t=1. In this case a revision of the first decision has to be considered. For the second decision the initial cash outflow CO_0 is irrelevant as only future payments can be relevant. The cash flows of the project have to be compared with the liquidation payment L_1. Sunk costs are defined as the difference between CO_0 and L_1. The smaller L_1 the larger is the share of the costs that are sunk and the more irreversible is the transformation of resources. Just taking into account transaction costs a rersource transformation is never completely reversible whereas the extreme of a completely irreversible resource transformation is realistic if the assets are completely specific. From a decision theoretic perspective sunk costs are no costs at all.[5] They cannot be recoverd by the way of liquidation. Outside the project no cash flows can be earned with the resources behind.

[4] For the following discussion see PEDELL (2000), pp. 69ff.

[5] See KIRZNER (1978), p. 154; BAUMOL/PANZAR/WILLIG (1988), p. 280.

The share of the costs that are not sunk is relevant for the decision in t=1.[6] The amount of costs sunk by investing in an asset is equal to the difference between the acquisition price in the primary market and the liquidation price in the secondary market of the asset.

A gap between the acquisition and the liquidation price of an asset can be explained by various reasons restricting the tradability of the asset:

- The asset itself or complementary assets are firm specific.[7] Specifity can be traced back among other things to causal ambiguities, social complexities and path dependences. Tacit knowledge and capabilities are examples for resources that are intangible and therefore cannot be traded without loss.
- Information asymmetries between sellers and buyers about the quality of assets lead to market failure by adverse selection as described in the model of the market for lemons.[8] If a potential buyer does not know the quality of a second-hand asset he is willing to pay only the price for the expected average quality. Potential sellers of high quality assets are not willing to sell for this price and withdraw from the market. Thus the average quality of the market continues to decrease until only the worst quality is traded.
- An information asymmetry cannot easily be removed if the considered asset itself is an information, because information cannot be valued without revealing it, a phenomenon called information paradox.[9] Even explicit knowledge as far as it is not protected by patents or other mechanisms cannot be traded without loss. Tacit knowledge cannot be formulated explicitly and therefore cannot be transfered and traded at all.
- Transaction costs have to be added to the acquisition price and subtracted from the liquidation price of assets. This drives a wedge between the individual acquisition and liquidation price of the firm even if the market prices do not differ. As transactions always take some resources, at least a certain time, sunk costs are a ubiquitous phenomenon.

In the end all these reasons cause market imperfectness or even complete market failure on the factor markets and create thereby profit opportunities. Depending on whether the actual liquidation price is compared to the historical or the actual acquisition price, a distinction can be made between historical or simultaneous sunk costs (see fig. 3).[10] Historical sunk costs measure the irreversibility of an investment by the firm as described above, whereas simultaneous sunk costs show the advantage in relevant costs the firm enjoys relative to its potential competitors thinking about entering the market. If the economic life and the efficiency units of an asset are limited, only the remaining efficiency units are relevant for competition. In this case the difference between the acquisition price and the liquidation price per unit has to be multiplied by the remaining efficiency units to calculate the volume of sunk costs. This volume indicates the competitive cost advantage. In order to found the statement that the firm enjoys a competitive advantage in relevant costs there is to be shown the decision irrelevance of sunk costs.

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6 Those costs can be interpreted as the exercise price of an option on the cash flows of the project. The analogy is not complete because this exercise price has not to be paid anymore but is renounced if the project is continued.

7 For the different types of specifity see WILLIAMSON (1985), pp. 95f.

8 See AKERLOF (1970).

9 See ARROW (1980), p. 38.

10 For the differentiation between simultaneous and historical sunk costs see KRAHNEN (1991), pp. 48f.; SCHAUB (1997), pp. 25ff.

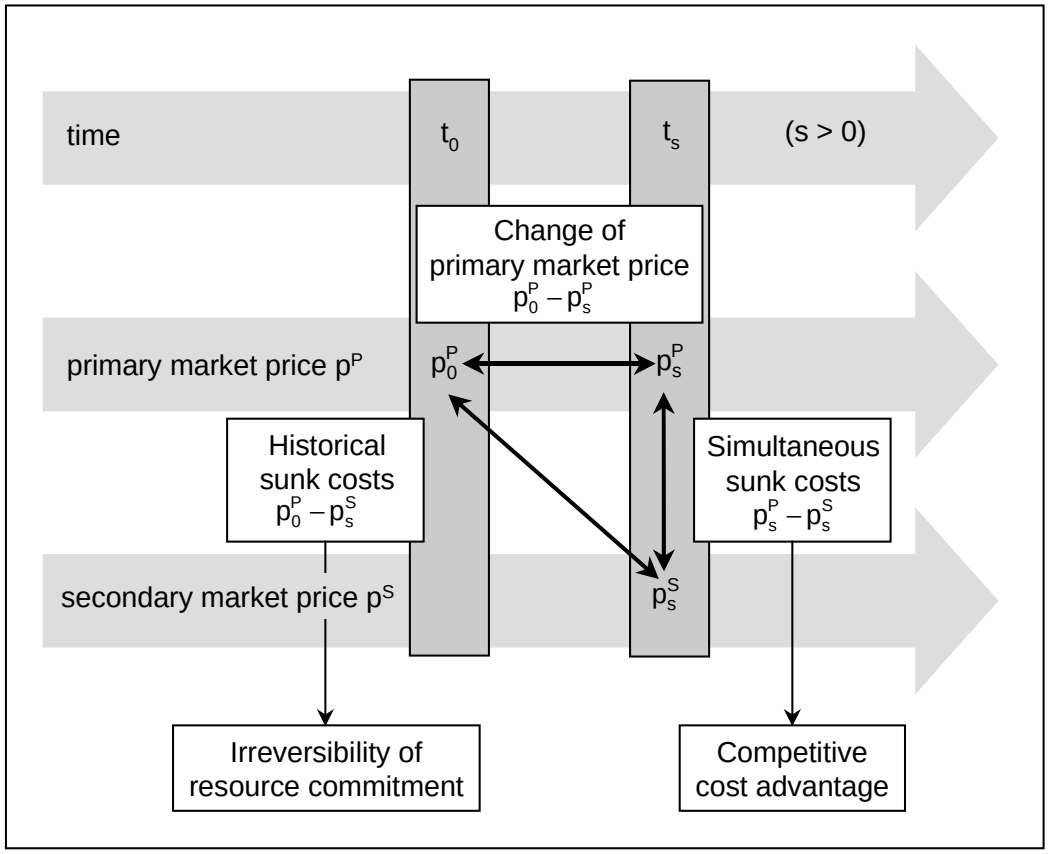

Fig. 3: Historical and simultaneous sunk costs

In general an information is decision relevant if it is *able* to change the choice or the order of decision alternatives. That means that it can effect a change of the target values of decision alternatives.[11] Under certainty payments can only be relevant in case of being possibly influenced by the decision variables of the considered decision. Decision relevant payments therefore have to be future, avoidable and alternative specific.[12] Due to the irreversibility of time past payments cannot be influenced. Future payments the firm is already commited to by contracts cannot be influenced any more neither. And under certainty costs that are identical for every considered decision alternative cannot change the order of alternatives. Even if they can be influenced in general, they cannot be influenced within the considered decision alternatives. In consequence the extent of sunkness of costs can depend on the considered decision alternatives. As part of past payments and payments the firm is commited to by past decisions, sunk costs are not relevant. Seen from the present decison theoretic perspective they constitute no costs at all.

Under uncertainty disposable certain payments that are identical for every decision alternative can be relevant. They change the wealth of the decision maker. If the decision maker is risk averse and his absolute risk aversion changes with his wealth, identical payments change his risk preferences. As a consequence his order of decision alternatives may change.[13]

How about past payments or future payments the firm already commited to in the past, resp. payments that induced sunk costs? From the present decision theoretic perspective those payments reduced irreversibly the wealth of the decision maker (see fig. 4). They cannot be influenced by present decisions. They have to be considered by the decision maker the moment he calculates his present wealth. This stock variable is relevant for the risk preference

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11 For the decision relevance of information see KOCH (1994), p. 40.

12 For an analog discussion of the relevance of costs see HORNGREN/FOSTER (1987), p. 301; SCHWEITZER/KÜPPER (1998), p. 443.

13 See ROTHSCHILD/STIGLITZ (1971); DOPUCH/BIRNBERGER/DEMSKI (1982); DILLON/NASH (1978); SCHNEIDER (1984).

of the decision maker if he has a variable absolute risk aversion. How this wealth has been realized by past payments (and liabilities to pay) is irrelevant for the decision. The present stock of wealth has been influenced by innumerable factors including past payments. Theoretically the factors behind the present wealth can be traced back infinitely. The decision maker cannot decide anymore if he is going to buy the asset. At most he can decide if, how and when it will be used. The stock of wealth separates the irrelevant flow of past payments (including liabilities to pay) from the relevant flow of future payments. Sunk cost as part of those past payments are decision irrelevant.

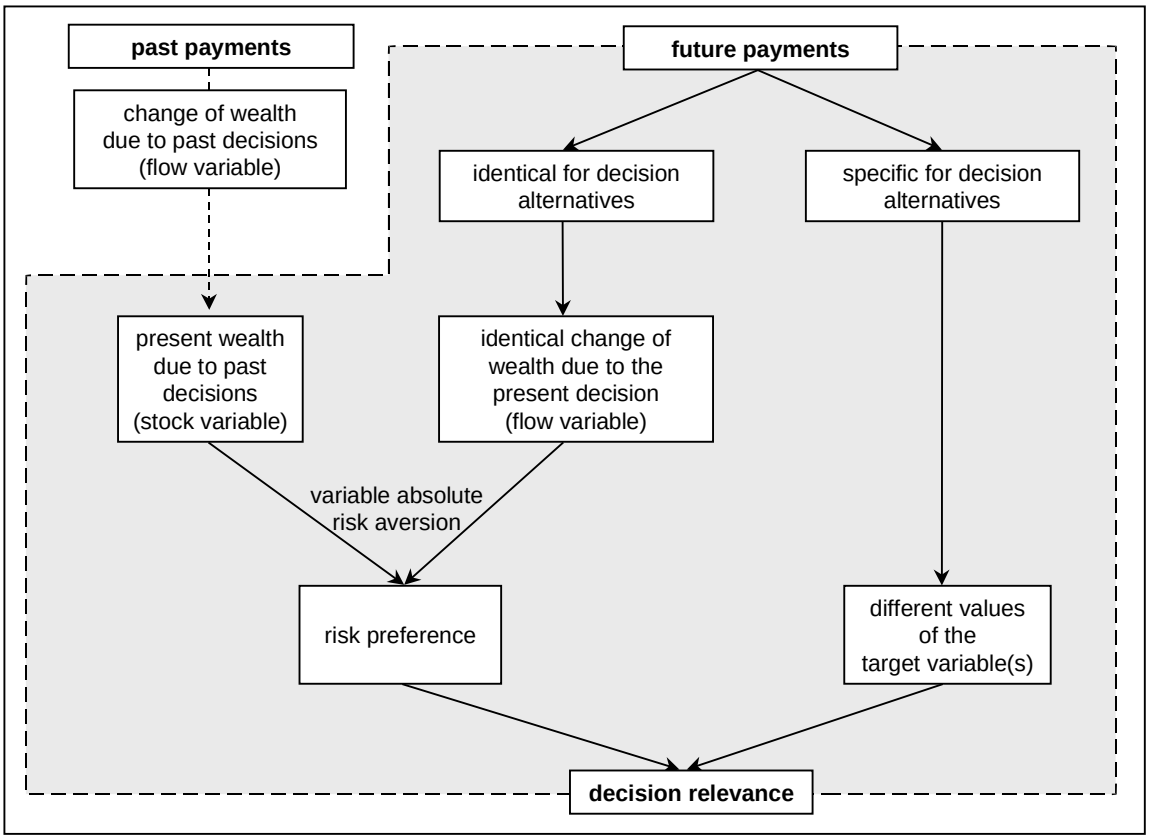

Fig. 4: Decision relevance of payments under uncertainty

Fig. 5 gives an overview of the decision relevance of payments. The grey shaded areas indicate decision relevant payments. Under certainty as well as under uncertainty past payments und especially sunk costs as part of these payments are decision irrelevant. Under certainty future payments identical for every decision alternative are irrelevant. Under uncertainty they are in so far relevant as they change the wealth of the decision maker and thereby possibly his absolute risk aversion. Payments that are specific for different decision alternatives only can be future payments and are always relevant because they influence directly the target variable.

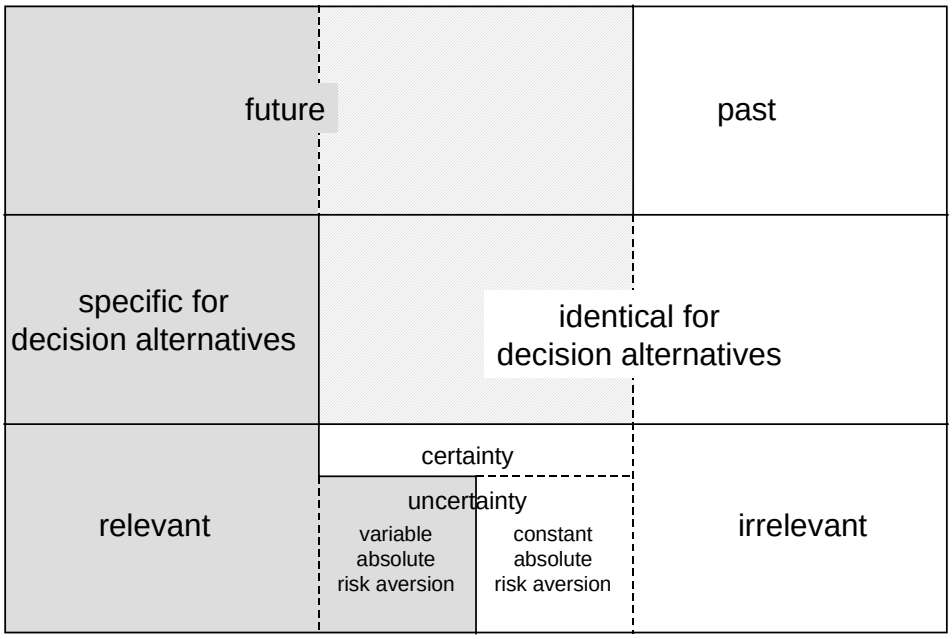

Fig. 5: Decision relevance of payments

The decision irrelevance of payments that induced ex post sunk costs makes these payments ex ante particularly relevant for the planning process because they change the competitive behaviour of the firm as is to be shown in section 3. The argument about the relevance of payments can be generalized and enlarged as shown in fig. 6.

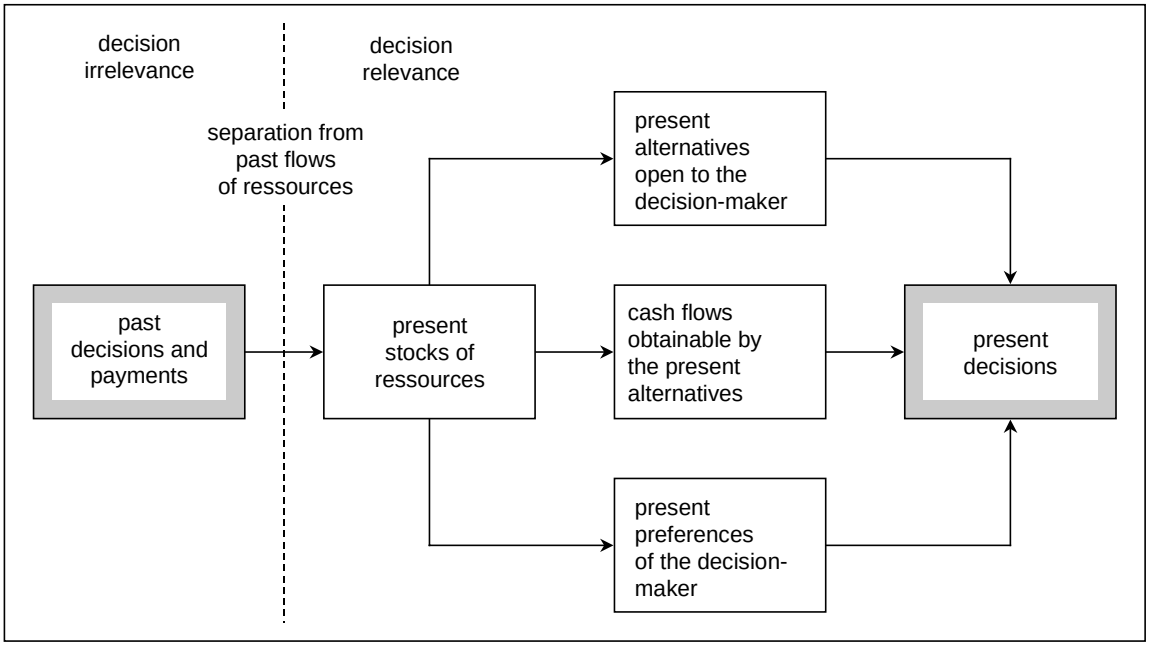

Fig. 6: Past and present decisions

Actual decisions are not only influenced by the present stock of money but by the present stocks of all resources. They decide which decision alternatives are open to the decision maker, which cash flows can be earned by these alternatives, and which preferences the decision maker has. Present decisions depend on how much capital is invested in which assets. The present stocks establish an interdependence between past and present decisions.[14] As it is irrelevant to which past decisions and payments the present stocks of resources can be traced back they separate present and past decisions because at the same time.

[14] For the effects of capital that cannot perfectly be reallocated see already MISES (1940), pp. 463ff.

Fig. 7 illustrates the two different sides of commitment to be discussed in section 3 and section 4. The irreversibility of an investment decision, measured by the extent of sunk costs, on one side provides the firm with an advantage in relevant costs over its competitors. On the other side under uncertainty an irreversible cash outflow not yet covered by cash inflow generates risk for the firm. As only irreversible decisions create risk, planning is only necessary if irreversible decisions are made.

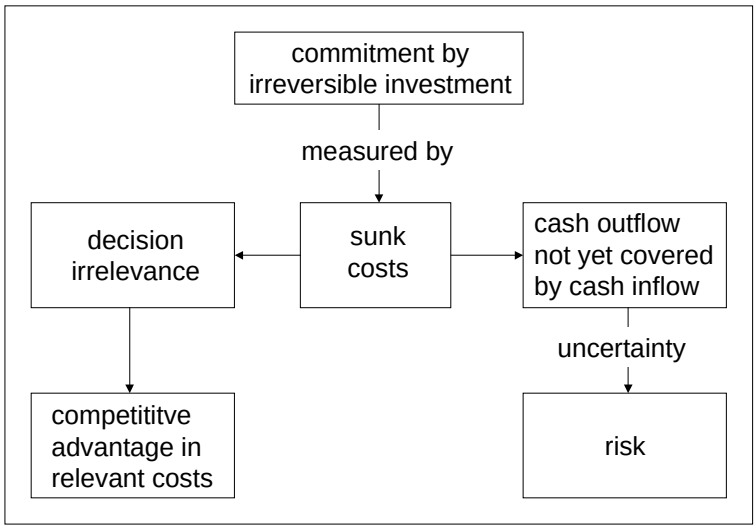

Fig. 7: Irreversibility, competitive cost advantage and risk

3. Competitive advantages attainable by commitment

In situations with strategic interaction between several players varied advantages can be attained by commitment.[15] Commitment can be used to make cooperation and collusion possible that otherwise could not be achieved because ex post, after the players have succeeded with specific investments in the cooperation, hazards of expropriation arise. Cooperation is possible if the players can commit themselves ex ante not to exploit these hazards of expropriation.[16] Furthermore advantages can be attained in bargaining situations which deal with the sharing out of cooperation gains.[17] Finally the firm's and competitors' behaviour in competition can be influenced by commitment to the advantage of the firm.[18] In the following discussion only commitment in competition is analyzed.

The advantages that can be gained in product market competition are analyzed in a simple two period duopoly model.[19] In period 2 the firm and its competitor compete in the product market. In period 1 the firm has the opportunity to commit itself by a strategic move, for example by investing irreversibly in specific capacity. The investment is assumed to be completely irreversible. It modifies the payoffs of strategy combinations in the product market in period 2 and thereby leads to a change of the expectations and the behaviour of the firm and its competitor in the product market.

Three characteristics are necessary for making the commitment change the expectations and the behaviour of competitors.

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15 „In a one player game ... commitments cannot be of value, as any payoff that a player could attain while playing according to the commitment could be attained by playing exactly the same way without being commited to do so." (FUDENBERG/TIROLE (1991), p. 74f.)

16 See WILLIAMSON (1983); MILGROM/ROBERTS (1992), pp. 136ff.

17 For commitment in bargaining situations see SCHELLING (1960).

18 For an overview of the advantages that can be attained by commitment see PEDELL (2000), pp. 107ff.

19 The model is taken from TIROLE (1988), pp. 207ff. and pp. 323ff.

1. Observability: The competitors must be able to observe the commitment, or more precise both the strategic move and the underlying force of commitment have to be observable.[20]
2. Comprehensibility: The strategic move has to be understood by the competitors as a commitment.[21]
3. Credibility: The strategic move has to be credible. Credibility can be achieved by the irreversibility of the strategic move or of complementary actions.[22]

In the second period both firms choose simultaneously their variables in the product market. The profit of firm *i* depends on its own variable x_i and the variable x_j of the competing firm.

$$\Pi^i = \Pi^i(x_i, x_j) \qquad i, j = 1,2 \tag{1}$$

The profit function of each firm *i* is assumed to be strictly concave in its own variable x_i ($\Pi^i_{ii}(x_i, x_j) < 0$).

The reaction function R_i of each firm is defined by the first order condition for a Nash equilibrium

$$\Pi^i_i(R_i(x_j), x_j) = 0\,. \tag{2}$$

The slope of the reaction functions can be derived from the total differential of (2) via the implicit functional theorem

$$\frac{dx_i^*}{dx_j} = R_i'(x_j) = \underbrace{\frac{\Pi^i_{ij}(R_i(x_j), x_j)}{\underbrace{-\Pi^i_{ii}(R_i(x_j), x_j)}_{<0}}}_{>0}. \tag{3}$$

The numerator of the fraction is always positive due to the strict concavity of the profit function in the firm's own variable. The slope of the reaction function therefore depends on the sign of Π_{ij}. A firm reacts with an increase (decrease) of its variable on an increase of the variable of its competitor if the increase of the variable of the competitor increases (reduces) the marginal profit of the firm as to its own variable. For $\Pi_{ij} > 0$ the variables are strategic complements and for $\Pi_{ij} < 0$ they are strategic substitutes.[23] The slope of the reaction function of strategic complements (substitutes) is positive (negative). Quantities usually are strategic substitutes, prices usually are strategic complements.[24]

In the first period the firm chooses the volume of the irreversible investment K_1. K_1 influences the product market variables x_1 and x_2 in the second period. The competitor observes K_1 and decides wether to enter the market or not. The firm influences its optimal choice of x_1 and via x_1 the competitors optimal choice of x_2. If the competing firm enters the market the two firms play a simultaneous duopoly game in the second period. Then the profits of the firms are defined as

$$\Pi^1 = \Pi^1(K_1, x_1, x_2) \quad \text{and} \quad \Pi^2 = \Pi^2(K_1, x_1, x_2)\,. \tag{4}$$

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20 See SHAPIRO (1989a), p. 389; (1989b), p. 127; DIXIT/NALEBUFF (1991), p. 130.

21 See SCHELLING (1960), p. 25; BESANKO/DRANOVE/SHANLEY (1996), p. 322.

22 See for example NEUSS/NIPPEL (1996).

23 For the definition of strategic substitutes and complements see BULOW/GEANAKOPLOS/KLEMPERER (1985a), pp. 491ff.; (1985b), pp. 180f.

24 This cannot be generalized but has to be checked empirically in every single analyzed market.

In the Nash equilibrium with mutual optimal reactions x_1* and x_2* depending on K_1 the profits are

$$\Pi^{1*} \equiv \Pi^1(K_1, x_1^*(K_1), x_2^*(K_1)) \quad \text{and} \quad \Pi^{2*} \equiv \Pi^2(K_1, x_1^*(K_1), x_2^*(K_1)) \tag{5}$$

If market entry of the competitor is not blockaded by a natural monopoly[25] of the firm,[26] the firm can choose between two fundamental strategic orientations in the product market (see fig. 8). It can permit the market entry of the competitor and change the behaviour of the competitor in the product market to its own advantage or it can prevent the market entry of the competitor. In every individual case it has to be checked by comparing the respective profits, if the prevention of market entry by K_1 is possible, and which of the two fundamental strategic orientations is preferable.

type of competition / type of competitor	coexistence	driving out
potential competitor	admit market entry and change market behaviour of competitors to your own advantage	prevent market entry
competitor established in the market	accept coexistence and change market behaviour of competitors to your own advantage	induce market exit

Fig. 8: Fundamental strategic orientations in the product market

3.1 Prevention of market entry

To prevent market entry the potential profit of the competitor has to be reduced to zero. The derivative of Π^2 with respect to K_1 indicates how this can be achieved.

$$\frac{d\Pi^2}{dK_1} = \frac{\partial \Pi^2}{\partial K_1} + \frac{\partial \Pi^2}{\partial x_1}\frac{dx_1^*}{dK_1} + \underbrace{\frac{\partial \Pi^2}{\partial x_2}\frac{dx_2^*}{dK_1}}_{=0} \tag{6}$$

The third term can be neglected in accordance with the envelope theorem.

$$\frac{d\Pi^2}{dK_1} = \underbrace{\frac{\partial \Pi^2}{\partial K_1}}_{\substack{\text{direct}\\ \text{effect}}} + \underbrace{\frac{\partial \Pi^2}{\partial x_1}\frac{dx_1^*}{dK_1}}_{\substack{\text{indirect}\\ \text{effect}}} \tag{7}$$

The effect of K_1 on Π^2 can be split up in a direct and an indirect effect.[27] The direct effect is independent of changes of x_1 in the product market competition in period 2. In addition K_1 has an indirect effect on Π^2. By the choice of K_1 in period 1 the firm can change its optimal choice of x_1 in period 2; this change of x_1 has an effect on the potential profit of the competitor in period 2.

Depending on wether the total effect is negative or positive the investment K_1 makes the firm more aggressive or defensive. If the firm aims on preventing the market entry of the

[25] For the definition of natural monopoly see EATON/LIPSEY (1981), p. 595.
[26] In this case the firm can maximize its monopoly profit as if there would be no competitor at all.
[27] See DIXIT (1986), pp. 111ff.

competitor it has to be that aggressive that the potential profit of its competitor is reduced to zero. Therefore the firm will overinvest with reference to the investment volume of a monopolist profiting from blockaded market entry if K_1 is an aggressive type of investment (see fields 1 and 3 in fig. 9) whereas it will underinvest[28] if K_1 is an defensive type of investment (see fields 2 and 4 in fig. 9).

3.2 Admittance of market entry

If the firm admits market entry of its competitor in period 2 it aims on maximizing its own profit by choosing K_1. So Π^1 has to be derivated with respect to K_1 to ascertain the profit maximum. On the analogy of section 3.1 the total effect can be split into a direct and an indirect effect:

$$\frac{d\Pi^1}{dK_1} = \underbrace{\frac{\partial \Pi^1}{\partial K_1}}_{\substack{\text{direct}\\ \text{effect}}} + \underbrace{\frac{\partial \Pi^1}{\partial x_2}\frac{dx_2^*}{dK_1}}_{\substack{\text{indirect}\\ \text{effect}}} \overset{!}{=} 0 \qquad (8)$$

The direct effect does not depend on changes of the competitors product market variable x_2 whereas the indirect effect is based on strategic interaction with the competitor. By the choice of the volume of the irreversible investment K_1 the firm can influence the competitors optimal choice of of x_2 which effects the profit of the firm.
To analyse the sign of the indirect effect equation (8) is transformed. According to the chain rule

$$\frac{dx_2^*}{dK_1} = \frac{dx_2^*}{dx_1}\frac{dx_1^*}{dK_1} = R_2'(x_1^*)\frac{dx_1^*}{dK_1} \qquad (9)$$

is obtained. Assuming that the effect of the product market variables of each firm on the profit of the other firm has the same sign

$$\text{sign}\,(\partial\Pi^1/\partial x_2) = \text{sign}\,(\partial\Pi^2/\partial x_1)$$

equation (8) can be rewritten as

$$\underbrace{\text{sign}\,(\frac{\partial \Pi^1}{\partial x_2}\frac{dx_2}{dK_1})}_{\substack{\text{indirect effect}\\ \text{on the firm's}\\ \text{own profit}}} = \underbrace{\text{sign}\,(\frac{\partial \Pi^2}{\partial x_1}\frac{dx_1}{dK_1})}_{\substack{\text{indirect effect}\\ \text{on the competitor's}\\ \text{profit}}} \quad \underbrace{\text{sign}\,(R_2')}_{\substack{\text{slope of the competitors}\\ \text{reaction function}\\ \text{(strategic substitutes}\\ \text{or complements)}}} \qquad (10)$$

without changing the signs. The sign of the indirect effect on the firm's own profit corresponds to the sign of the indirect effect on the competitor's profit multiplied with the sign of the slope of the competitors reaction function. This sign is positive (negative) for strategic complements (substitutes). Assuming that $\partial\Pi^2/\partial K_1 = 0$, a negative (positive) indirect effect on the competitor's profit is tantamount to an aggressive (defensive) type of investment. As the firm aims at maximizing its profit it will overinvest (underinvest) if the sign of the indirect effect on the firm's own profit is positive (negative). Overinvestment respectively underinvestment refer to the open loop equilibrium without strategic interaction.[29] Fields 5 to

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[28] A commitment to underinvestment is only possible, if the investment cannot be delayed without a loss resp. investment now and later have not to be perfect substitutes (see FUDENBERG/TIROLE (1984), p. 364). If investment cannot be delayed at all there is a now-or-never-decision.

[29] See SHAPIRO (1989a), pp. 382ff.

8 in fig. 9 summarize the possible combinations of investment types and product market variable types if market entry is admitted. With strategic substitutes the firm increases its profit by being more aggressive. So the firm overinvests (underinvests) if the investment type is aggressive (defensive). With strategic complements the firm reduces its profit by being more aggressive. So it underinvests (overinvests) if the investment type is aggressive (defensive).

Strategic Orientation	Prevent market entry		Admit market entry and change market behaviour of competitors to maximize the firm's profit	
Strategic Target	Reduce the potential profit of the competitor in the second period to zero		Make behaviour of the competitor in the second period defensive to maximize thereby the firm's profit	
Type of Investment	Irreversible investment makes the firm ...		Irreversible investment makes the firm ...	
	...aggressive $\frac{d\Pi^2}{dK_1} < 0$	**...defensive** $\frac{d\Pi^2}{dK_1} > 0$	**...aggressive** $\frac{d\Pi^2}{dK_1} < 0$	**...defensive** $\frac{d\Pi^2}{dK_1} > 0$
Strategic Substitutes in the Product Market $R_2'(x_1^*) < 0$	1 **aggressive overinvestment to become aggressiv**	2 **defensive underinvestment to become aggressive**	5 **aggressive overinvestment to become aggressiv**	6 **defensive underinvestment to become aggressive**
Strategic Com-plements in the Product Market $R_2'(x_1^*) > 0$	3 **aggressive overinvestment to become aggressiv**	4 **defensive underinvestment to become aggressive**	7 **aggressive underinvestment to become defensive**	8 **defensive overinvestment to become defensive**

Fig. 9: Taxonomy of Competitive Strategies[30]

Fig. 10 illustrates the above by a comparative static analysis of the reaction functions. Fig. 10a[31] shows the case of admitted market entry with strategic substitutes. The firm wants to be more aggressive That means it overinvests (underinvests) if the investment type is aggressive (defensive) and thereby shifts its reaction function to the right. The equilibrium in B is on a higher indifference curve than the one in A. If the intersection of the shifted reaction function of the firm and the competitors reaction function lies on the x_1-axis, prevention of market entry results as a corner solution.

If the potential competitor has to bear fixed costs of market entry, it has a kinked reaction function as shown in fig 10b[32]. Below a certain break-even quantity these fixed costs are not covered, the competitor does not enter the market and the reaction curve falls down to zero. The established firm can prevent market entry of the potential competitor by making itself more aggressive (aggressive overinvestment or defensive underinvestment) and pushing its own reaction curve to the right, so that it intersects with the horizontal part of the competitor's reaction function on the x_1-axis.

The higher the fixed costs of market entry of the potential competitor are, the higher is the minimum quantity required to cover these fixed costs (the more left lies the vertical part of the competitor's reaction function) and the smaller is the capacity of the firm by which it can

30 Extended overview based on TIROLE (1988), p. 327.
31 See TIROLE (1988), p. 316.
32 See DIXIT (1981), p. 99.

prevent market entry of the potential competitor. Fixed costs of the potential competitor help the established firm to prevent market entry.[33] Fixed costs of the established firm do not constitute an effective entry barrier, because potential competitors are attracted by supernormal profits and are ready to replace the established firm if they face the same cost function. Only irreversible investment in market entry which reduces the relevant costs of the established firm enables the established firm to benefit from the fixed costs of the potential competitor. Consequently the shift of the established firm's reaction function is measured by sunk costs not by fixed costs. The entry barrier of the potential competitor results from an exit barrier of the established firm due to the immobility of capital.

Fig. 10c illustrates admittance of market entry with strategic complements. Higher iso-profit-lines represent higher levels of profit. The firm can increase its profit by making its competitors behaviour more defensive. With strategic complements that means that the firm has to make its own behaviour more defensive. This corresponds to a shift to the right of its reaction curve by an aggressive underinvestment or a defensive overinvestment.

The case of prevented market entry with strategic complements is illustrated in fig. 10d. It is assumed that the iso-profit-line of the competitor running through B represents a profit of zero. Left of B the competitor makes a loss and is prevented from market entry. For the firm this corresponds to infinitely high prices of the competitor which is indicated by an upward kink of the competitor's reaction curve. If the firm shifts its reaction curve far enough to the left, so that the intersection with the competitor's reaction curve is above B, market entry is prevented. The shift to the left can be induced by an aggressive overinvestment (defensive underinvestment).

Wether admittance or prevention of market entry is advantageous for the firm, only can be assessed by comparing the profits of the two alternative strategies. With strategic substitutes both strategies ask for aggressive overinvestment (defensive underinvestment). With strategic complements prevention of market entry under certain circumstances can be achieved by an aggressive overinvestment (defensive underinvestment) whereas an aggressive underinvestment (defensive overinvestment) increases the firm's profit if market entry is admitted.

[33] See GEROSKI/GILBERT/JACQUEMIN (1990), p. 30.

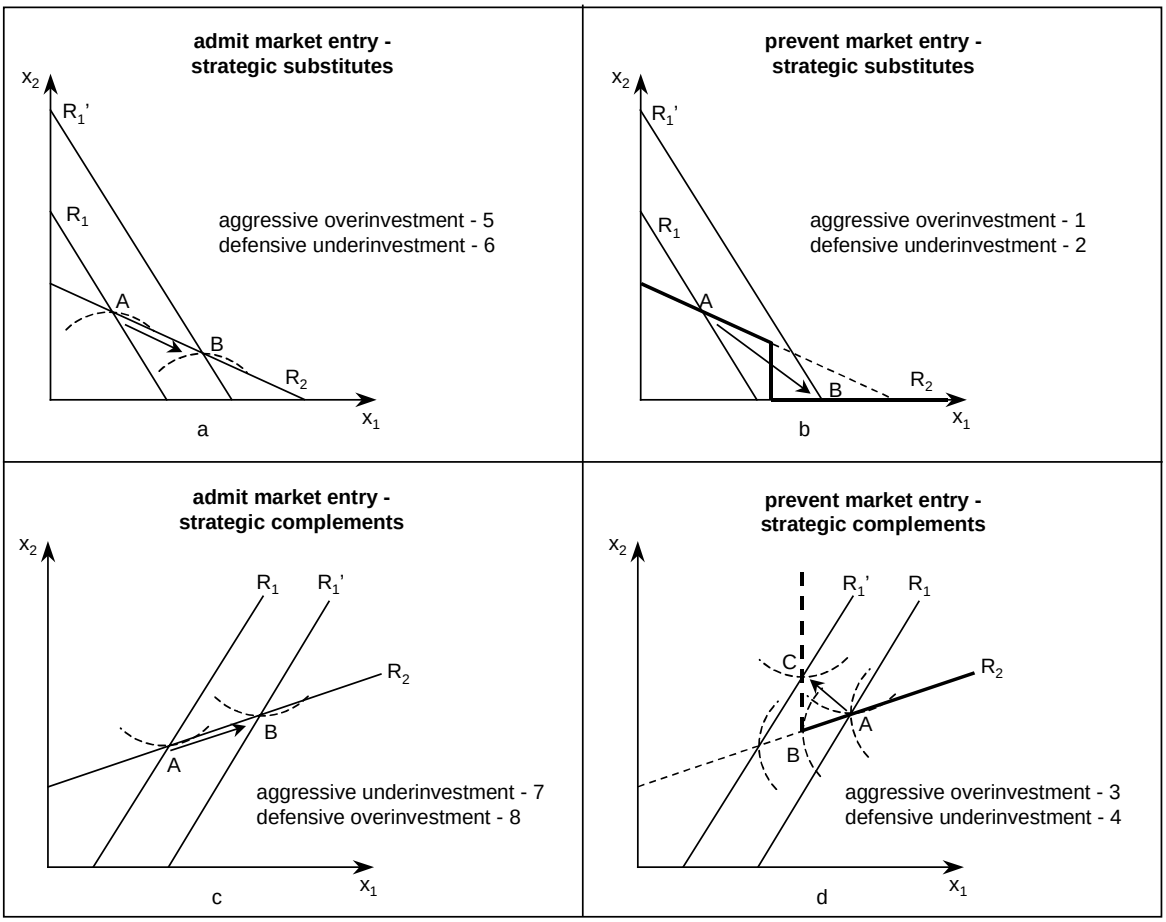

Fig. 10: Comparative statics of the competitive effects of commitment

The irreversible investment changing the established firm's reaction curve not only can be an investment in product specific capacity but can take the most various forms.[34] An aggressive type of investment for example can be an investment in learning-by-doing, in the installed base of network products, in a related market with positive demand interdependences or in horizontal mergers with synergies due to economies of scale. The aggressive act as well can consist in implementing a compensation scheme that makes the responsible product manager behave more aggressive or in raising the debt-equity-ratio which sets an incentive to take higher risks if the firm has limited liability. An example for a defensive type of competitive act is investment in customer loyalty by advertising. If customers acquired in the past are ready to pay a price premium the incentive to lower prices to acquire new customers is reduced. The same argument holds for customers commited to specific products that induce switching costs because their use requires specific learning or specific complementary assets.

In any case the sustainability of competitive advantages, resp. supernormal profits by entry barriers can be traced back to a commitment to specific resources. Irreversible investment in specific resources makes costs sink, lowers the relevant costs and thereby gives the firm a cost advantage over its competitors. The specifity of resources is due to imperfectnesses of resource markets. Arbitrage, resp. communication between resource market and factor market is imperfect. These imperfectnesses open up profit opportunities for a firm transforming resources into products. Entrepreneurship consists in trying to discover and exploit these opportunities.[35]

The sustainability of both, cost leadership and differentiation strategies, is based upon commitment to specific resources. Commitment is the crucial mechanism to attain

34 For a detailed overview see PEDELL (2000), pp.147ff. and pp. 258ff.
35 See KIRZNER (1978), p. 69.

competitive advantage in the dimensions product cost and product value. The present competitive position depends on which irreversible decisions have been taken in the past.

4. Optimal Volume and Timing of Commitment

Under uncertainty the advantages of a commitment by irreversible investment must be contrasted to the foregone value of an option to defer investment. In chapter 2 it has been indicated that under uncertainty irreversible investment creates risk (see fig. 7). Definitive cash outflows are expected to be regained by still uncertain cash inflows only after a certain time delay.[36] Expected sunk costs reflect the expected potential loss the firm might have to suffer in case of investing irreversibly. If the investment decision is a now-or-never-decision, the firm cannot choose the timing of investment and only has to consider this risk by trading it off against the potential competitive advantages attainable by commitment. The risk of loss lowers the incentive to invest[37] and the optimal volume of investment.[38] In section 3 the strategies of overinvestement and underinvestment shown in fig. 11 have been derived.

Strategic Orientation	Prevent market entry		Admit market entry and change market behaviour of competitors to maximize fhe firm's profit	
Commitment makes the firm..	**...aggressive**	**...defensive**	**...aggressive**	**...defensive**
Strategic substitutes in the product market	1 aggressive overinvestment to become aggressive **goal conflict**	2 defensive underinvestment to become aggressive **goal comple-mentarity**	5 aggressive overinvestment to become aggressive **goal conflict**	6 defensive underinvestment to become aggressive **goal comple-mentarity**
Strategic complements in the product market	3 aggressive overinvestment to become aggressive **goal conflict**	4 defensive underinvestment to become aggressive **goal comple-mentarity**	7 aggressive underinvestment to become defensive **goal comple-mentarity**	8 defensive overinvestment to become defensive **goal conflict**

Fig. 11: Investment volume, competitive effects of commitment and risk avoidance

Competitive strategies of overinvestment induce a goal conflict with the avoidance of risk whereas competitive strategies of underinvestment and the avoidance of risk are complementary because both ask for a reduction of investment volume.[39] In the latter case there is a goal complementarity in changing competitors' behaviour and keeping alive one's own freedom of action. The same trade-offs hold, if the investment is no now-or-never-decision but the firm can defer the investment for a certain time. In this case the additional question of the optimal timing of investment arises.

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36 See HAUER (1990), pp. 50f.

37 This can be taken into consideration by adjusting the discount rate.

38 Decision makers are assumed to be risk-averse.

39 The direct effects of commitment and the creation of new investment opportunities, which increase the incentive to invest, are not considered.

Fig. 12 shows the conditions that have to be fullfilled for the existence of a valuable option to defer investment.[40] First the investment decision must be deferrable otherwise the investment opportunity is not open anymore at a later moment and so there exists no option to defer investment at all. Second the investment decision must be at least partially irreversible. Otherwise the option could not be of any value because the firm could invest now and disinvest at any later moment without any loss. In this case the option to defer investment can not have any value except for the gain in interest. Third there must be uncertainty about the advantageousness of the investment. Strictly speaking, there must be contingencies under which the investment is disadvantageous and the firm would prefer to reverse the investment decision. Under certainty the advantageousness of the investment could be predicted perfectly and no deviation from the planned course of action could happen. Fourth the firm expects additional information in the future about the advantageousness of the investment project.[41] Ohterwise it could invest right now without foregiving a potential gain in information.

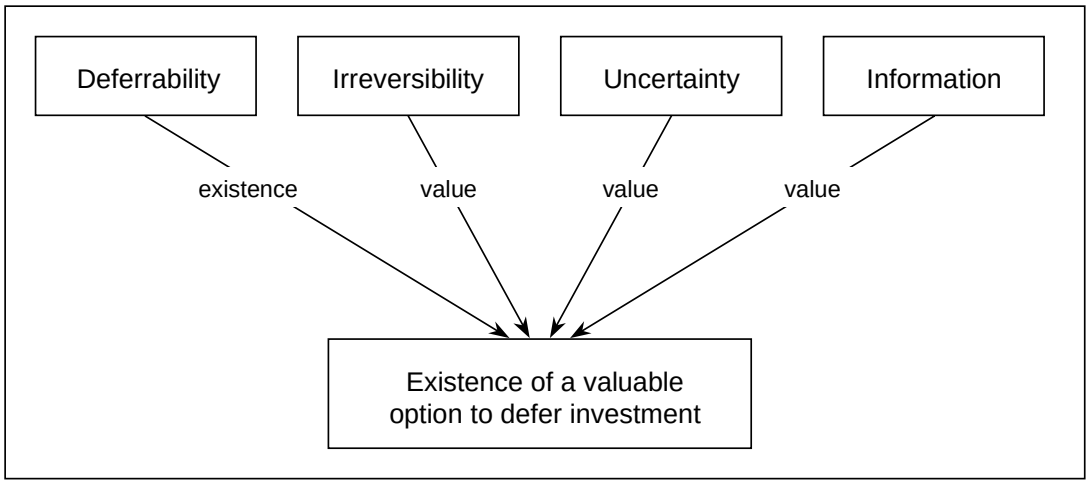

Fig. 12: Conditions for the existence of a valuable option to defer investment

With these four conditions fullfilled immediate commitment means foregiving a valuable option to defer investment. The opportunity to delay investment and wait for additional information is given up. By investing the option is exercised and the option value is extinguished. The discounted cash flow of the investment not only must be larger than the initial payment to induce immediate investment but also must compensate for the foregiven option value. Irreversibility reduces the incentive to make a premature investment before the latest possible moment of investment. This argument holds independent of the decision maker's attitude towards risk. The reduction in the incentive to invest only results from the extinguished option value.

The real option's approach[42] uses the analogy between an option to defer investment and a financial call option on a stock to identify the drivers of the optimal timing of investment. The value of a call option C can be calculated by the Black-Scholes-formula:[43]

$$C = Se^{-\delta T} N(d_1) - Xe^{-rT} N(d_2) \qquad (11)$$

[40] See PEDELL (2000), pp. 175ff.

[41] See already MARSCHAK (1949), p. 195.

[42] For the idea that irreversible investment kills an option see ARROW/FISHER (1974); HENRY (1974). The expression 'real option' has been coined by MYERS (1977). For an overview of the real option approach see DIXIT/PINDYCK (1994); TRIGEORGIS (1995); (1996).

[43] See BLACK/SCHOLES (1973), p. 149.

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) + \left(r - \delta + \frac{\sigma_S^2}{2}\right)T}{\sigma_S \sqrt{T}}$$

$$d_2 = d_1 - \sigma_S \sqrt{T}$$

S = stock price

T = time to expiration

X = exercise price

r = riskless interest rate

$N(\,)$ = density of the standard normal distribution

δ = rate of foregone dividends

σ_S^2 = variance of stock price

Based upon this formula fig. 13 shows the analogy of the value drivers of an option to defer investment and of a financial call option as well as the direction of their influence on the value of the respective options.[44]

The higher the expected present value of the cash flows of the investment opportunity is and the lower the initial payment for the investment is, the higher is the likelihood that the investment is made (that the option is exercised) immediately before the opportunity disappears. This increases the value of the option. A higher volatility also increases the value of an option.[45] Because of the asymmetric risk profile of an option, the likelihood of high profits is increased by a mean preserving spread of volatility whereas the likelihood of losses is unchanged because in case of loss the option will not be exercised. A higher riskless interest rate reduces the present value of the payment for the investment. The longer the remaining time to expiration is, the stronger gets this effect. Above that a longer remaining time increases the total variance of the present value of the cash flows at the moment of investment and therefore has the same effect as an increase in volatility per period. Higher foregone cash flows and suffered competitive disadvantages reduce the value of the investment and thereby the value of the option, increasing the likelihood of premature investment.[46] A weak correlation between a stochastic present value of the cash flows and a stochastic initial payment increases the likelihood that the difference between the two is high at the moment of investment and therefore increases the option value.[47] The importance of risk for the optimal timing of investment compared to the interest rate is underlined.

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44 See KESTER (1996), p. 5.23; INGERSOLL (1987), pp. 319f.; TRIGEORGIS (1988), p. 149; PINDYCK (1991), pp. 1114ff.

45 This is contrary to the influence of volatility on the passive net present value. The more volatile is the project value the higher is the discount rate and the lower is the net present value.

46 Without disadvantages of delay the investment is made at the latest possible moment.

47 See MCDONALD/SIEGEL (1986); CHEUNG (1993), p. 40.

value driver of an option to defer investment	value of an option to defer investment / of a call option	value driver of a financial call option on a stock
(gross) present value of the cash flows of an investment	▲	stock price
initial payment for the investment	▼	exercise price
time until opportunity disappears	▲	time to expiration
standard deviation of the discounted cash flow	▲	standard deviation of stock price
riskless interest rate	▲	riskless interest rate
foregone cash flows and competitive disadvantages due to postponement	▼	foregone dividends

Fig. 13: Value drivers of an option to defer investment

Fig. 14 gives an overview of the most important drivers of the optimal timing of commitment by irreversible investment.[48] It can be said that an early investment tends to be advantageous

- if competitors have access to the same investment opportunity and if the loss induced by competition[49] is big and avoidable by an early investment.
- if high cash flows of the investment are foregiven by delaying it.
- if investment procures the firm with a gain in information which improves the quality of related investment decisions.
- if the gain in interest from a postponement of investment is low.
- if flexibility is of low value due to low uncertainty.

On the other side investment is carried out late if the investment opportunity is open exclusively to the firm because it is protected by market entry barriers or by an information lead over potential competitors.[50]

If market entry is blockaded it is sufficient to make the investment early enough to preempt competitors without adjusting the investment volume to competitive interaction. If competitive interaction makes overinvestment the favourite competitive strategy, the goal conflict between preempting competitors by an early and high investment on one side and keeping alive the option to defer investment on the other side is particularly strong.

48 See PEDELL (2000), pp. 245ff.

49 This is the loss that a firm suffers if a competitor exercises a shared investment opportunity while the firm is keeping alive the option to defer investment.

50 See LAUX (1993), p. 955.

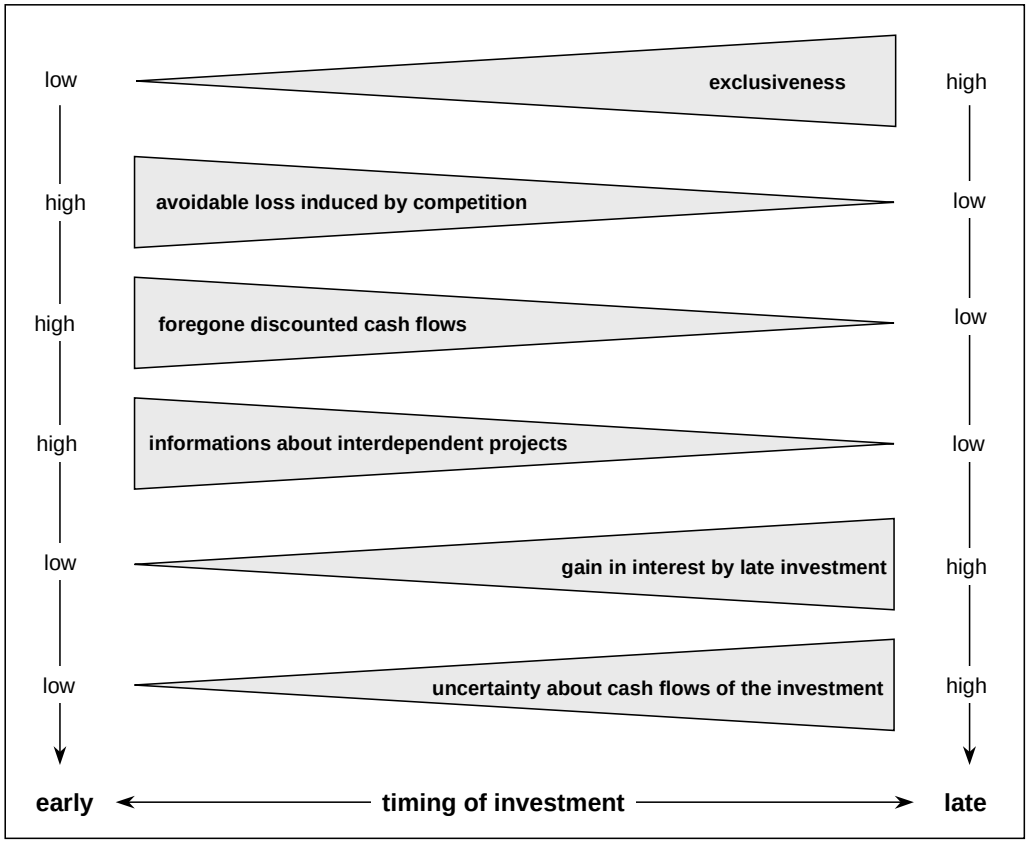

Fig. 14: Drivers of the optimal timing of investment

The value of an investment opportunity as well as the optimal timing and volume of investment depend on the individual stocks of resources of a firm (including e.g. individual information). These stocks decide which investment alternatives are open to the firm and which cash flows can be obtained by them; they establish path dependences with past investment decisions (see fig. 6 in section 2). This is particularly true for specific, irreversible investment the firm is commited to. Only this type of investment is able to give the firm a competitive advantage in relevant costs.

5. Synopsis - Interdependences of the Effects of Commitment

In fig. 15 a synopsis of the potential effects of commitment and their interdependences in the course of time is evolved.[51] It is taken into consideration that a commitment by irreversible investment in general exercises an existing option to defer investment and realizes thereby the passive net present value[52] of an investment project. Above that commitment is able to build market entry barriers. Investment in specific resources opens up new investment (and disinvestment) opportunities.[53,54]

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51 See PEDELL (2000), pp. 247ff.

52 The passive net present value assumes passive behaviour of the firm and its competitors. This is the special case of an exclusive now-or-never-investment. See BREALEY/MYERS (1996), p. 591; TRIGEORGIS (1988), p. 148.

53 Disinvestment opportunities are created if the investment is only partially irreversible, that means the costs are not completely sunk.

54 If investment opportunities are created by a commitment, the investment makes the firm the more aggressive the more exclusive it can benefit form the created options and advantages.

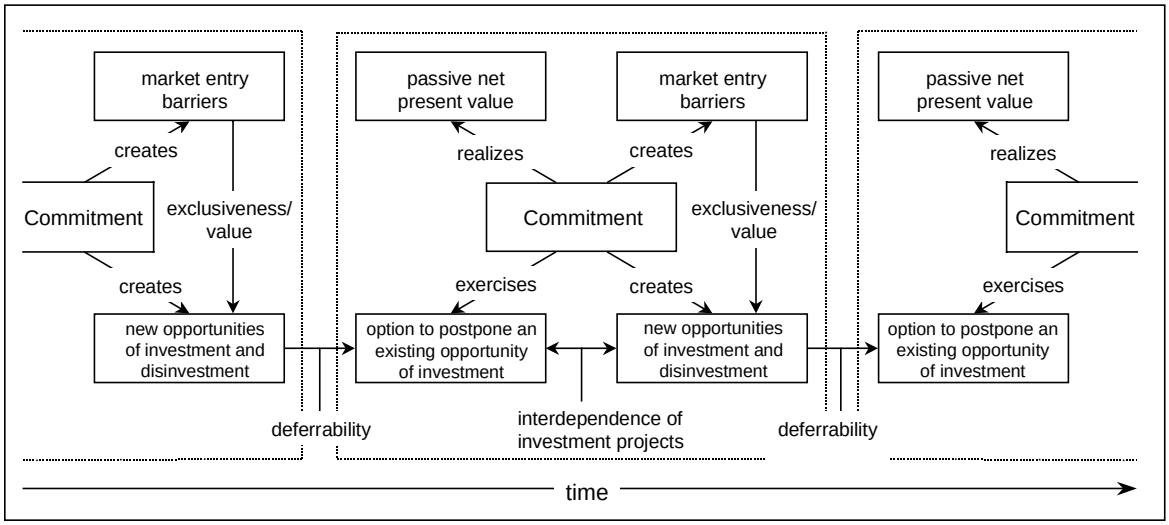

Fig. 15: Synopsis of the potential effects of commitment

These effects are subject to a number of potential interdependences: The better an investment opportunity is protected by existing market entry barriers, the more exclusive and valuable it gets and the later it tends to be exercised. On the other side new entry barriers only are build by early preventive investment. These new entry barriers protect future investment opportunities and thereby increase their value. The value and timing of present and future investment opportunities are interdependent. On one side, irreversible investment creates risks and makes deferrability valuable, on the other side, it makes it possible for the investor to build market entry barriers, which makes him willing to take risks.[55] The more these new entry barriers increase the value of future investment opportunities the earlier present investment opportunities are carried out. The earlier present investment opportunities are exercised the better future investment opportunities are protected against competition and the later those are exercised. The other way round, high uncertainty about the advantageousness of present investment opportunities causes the firm to invest relatively late. In consequence entry barriers are low, future investment opportunities are less protected against competition and exercised earlier.

These dependences and interdependences make very clear that commitment by irreversible investment, strategies to attain competitive advantage and the evolution of resource stocks cannot be judged isolated but ask for an integrated view.

The decision makers responsible for the investment and disinvestment strategies of a firm must be aware of the multiple potential effects that commitment by irreversible investment can have. They have to develop a deep understanding for the trade-offs to which decisions about the timing and volume of irreversible investment are subject to. On one side irreversible investment means killing valuable options, on the other side new options are opened up for the future and market entry barriers are build. The management has to put a focus on keeping the equilibrium between exercising existing investment opportunities and creating new investment opportunities. Sunk costs as a measure for the irreversibility of investment are an indicator for indentifying the key investment decisions of a firm. They are potential sources of competitive advantage and risk. Risk management and management accounting should direct particular attention to sunk costs.

[55] Without these entry barriers no investor would be willing to take any risk resp. to act at all, because otherwise his irreversible investment would be depreciated by the smallest inefficiencies (see HAYEK (1941), p. 311).

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