What Fraction of a Capital Investment is Sunk Cost?

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Abstract

In order to determine to what extent capital investments are sunk costs this study deals with salvage values of discarded metalworking machinery. Even though these assets are expected to be non-specific many of the discarded assets are scrapped rather than sold on second-hand markets. Econometric results suggests that firms can only expect to get back 20-50 percent of the initial price for a "new" machine once it is installed. The results also show differences in value-age profiles across firms, but give only weak support for the hypothesis that salvage values are particularly low in recessions.

Keywords: Sunk cost; second-hand market; salvage value; machine tools.

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I. Introduction

In this paper I consider the prices paid for used capital assets, in particular the sunk cost component of capital investments. The extent to which an asset is sunk cost is dependent upon the characteristics of both the asset and the second-hand market. Salvage values are typically higher for non-specific assets with liquid second-hand markets such as trucks, aircraft, and office buildings than for equipment tailor made to the requirements of the initial owner. In addition to asset specificity, informational asymmetries between sellers and buyers regarding asset quality may lead to low prices of second hand assets. In this study I examine salvage values of metalworking machinery used in Swedish manufacturing industries. One would *a priori* expect that these assets are of a general-purpose character (non-specific) for which there are second-hand markets with many potential buyers who are able to judge the quality of the pieces. Importantly, the present data set includes information of all assets that a sample of firms either scrapped or sold. Hence, here it is possible to account for the loss of value on pieces that were not even possible to sell, in contrast to previous studies that have only had information on assets that were actually sold. The assets in the sample can therefore provide a benchmark of the salvage values of recently installed capital assets.

The fraction of a capital investment that is sunk cost has been an important, but quantitatively largely unknown, building block in many economic models. Sunk cost is an often-stressed determinant of entry/exit decisions and strategic investment, Baumol and Willig (1981), Dixit (1980), and Eaton and Lipsey (1980). Empirical works that demonstrate the importance of sunk costs for competition include Kessides (1990) and Sutton (1991, 1998). In economic relations asset specificity and sunk costs may lead to *ex post* opportunism and can therefore influence *ex ante* contracting between agents, Williamson (1975), Klein et al (1978). Even in a non-strategic framework the sunk cost component is an important factor in investment decisions not only because low salvage values reduce the net present value of a given investment. In recent work on the timing of investments under uncertainty the presence of sunk costs introduce an option value of waiting for new information and delaying irreversible decisions, Dixit and Pindyck (1994).

Previous empirical studies, with the exception of Ramey and Shapiro (1998), of capital asset depreciation have not focused on the sunk cost component, but instead on the gradual decline in value as a reflection of the decline in productive efficiency. Under the assumption of frictionless second-hand markets it is possible to use prices paid for used assets to deduce the sum of the decline in efficiency and obsolescence of capital as it ages which is important in assessing the efficiency and value of aggregated capital stocks.[1] However, the price paid for used capital will also be a function of the properties of the second-hand markets which, if inefficient, may drive a wedge between the value of capital inside and outside the firm.

Figure I gives a schematic illustration of some of the issues involved. The functions I(AGE) and S(AGE) shows the initial owner's and the best secondary user's valuation of a capital asset as a function of its age. The negative relation between the valuation and age is due to a loss of production efficiency due to wear and tear as the asset ages. S(AGE) will be lower the more firm specific the asset is (such that for non-specific assets the difference between I(AGE) and S(AGE) will be small). If second-hand markets were frictionless then the asset would change owner at T1. This is the implicit assumption in works using second-hand prices to deduce the decline in productive efficiency (e.g., Beidleman (1973) and Hulten and Wykoff (1981)). However, for high transaction costs (HIGH TC) the asset will be retained until T2 when it is finally scrapped. With low transaction cost (LOW TC) the asset will change hands some time after T1 (assuming that the transaction cost is ultimately borne by the buyer it will cause a shift down of S(AGE)). If assets are discarded due to some exogenous change in production requirements for the current owner then the horizontal difference between I(AGE) and S(AGE) provides an estimate of the specificity of the asset. In particular at AGE=0 the difference is the sunk cost component of capital investments, defined to be the difference between what the initial owner paid for a newly installed asset and the best secondary user's valuation. Even though I(AGE) and S(AGE) are drawn as straight lines they may be some non-linear functions (for example log-linear which corresponds to constant

[1] For references on theoretical and econometric studies and more exact relationships between depreciation and decay in efficiency according to certain patterns see Hulten and Wykoff (1981) and Jorgenson (1989).

depreciation rates) and considerable effort has been devoted to find the value-age profiles for different goods. Fixed transaction costs in trading used assets may be of greater importance to assets with certain characteristics. Specifically, older assets and those that are inexpensive as new are more likely to be scrapped since to a buyer it is not worth to incur the fixed costs for an asset that will only be used for a few years and is anyway cheap to buy new.

[FIGURE I ABOUT HERE]

Some remarks on second-hand prices of used capital assets are important to make before proceeding. Informational asymmetries between informed sellers and uninformed buyers on the quality of an asset may lead to an equilibrium with prices reflecting low quality and only low quality assets (lemons) entering the market, Akerlof (1970). In the figure, I(AGE) and S(AGE) would, in equilibrium, be the valuations of an asset of low quality. However, uninformed buyers is typically not a reasonable description of the demand side in second-hand markets for machinery where, as noted by Beidleman (1973), most of them are professionals and well capable of judging the quality of a machine. Discussing the matter with the firms in the sample and machine dealers also indicates that the prices do not correspond to those of lemons. Another potential problem is capital embodied technological progress which would tend to make economic depreciation faster (by making I(AGE) and S(AGE) steeper). Capital embodied technological progress raises the question about the appropriate price deflator, an issue discussed below. However, the rate of technological change in the majority of metalworking machinery is probably low, Oliner (1996).[2] This is supported by the survey of Prais (1986) which showed assets of widely varying age side by side, something one would not see were capital embodied technological progress crucial (c.f. personal computers).

[2] There is a growing importance of numerically controlled metal working machinery, where there is reason to believe technological progress is faster. Oliner (1996) estimates that 25 percent of the new investment in machine tools the U.S over the period 1985-89 were numerically controlled, compared to 17 percent in 1979-83.

II. Data

The data were collected directly from firms in Swedish manufacturing industries and contain information on discarded (sold or scrapped) metalworking machinery. The first sample was primarily collected in 1990-91 from four firms and contains assets that were discarded 1983-90. It is compared to a similar sample collected in 1960 with information on machines discarded 1954-59 by six firms. The first criterion in the selection of firms was that metalworking machinery should be a major part of their production equipment. To gain access to the necessary data the final samples of firms were selected on the basis of previous co-operation in research projects initiated by the Industrial Institute of Economic and Social Research (IUI). Table I gives a brief description of the firms and their lines of production, as well as the years the assets were discarded.[3] The firms were primarily operating in industries with ISIC codes 381 (metal products), 382-3825 (non- electrical machinery, excluding office and computing machinery). Two of the firms in the 1990 sample were producing parts for cars and aircraft. Assets were not discarded in major divestments, but rather as a matter of day to day business operations, for example due to capacity adjustments or changes in production requirements. Scanning through the firms' annual reports in the years the assets were discarded did not reveal anything unusual, such as sharp falls in demand or substantial

[3] Most of the 1990 sample was collected by the author but the data from Asea Robotics were collected in 1988 by Christina Hartler. Some other firms were contacted but did not have sufficient records of their discarded machines to make statistical analysis meaningful. The earlier sample was collected in 1960 by Jan Wallander, and presented in Wallander (1962).

changes in operating profits.[4] The years 1983-85 and 1988-90 were years with medium to high growth rates in the economy and the manufacturing sector, while the period 1986-87 saw a mild recession. The earlier sample period, 1954-59, were years with persistent high growth rates.

[TABLE I ABOUT HERE]

The machines are primarily lathes, drilling machines, milling cutters and presses. Ideally one would like to estimate salvages values for each type separately but this is not feasible given the small samples. However, a similar aggregation has also been used in previous studies (e.g., Hulten and Wykoff, 1981) and has the advantage of giving a broad picture of the salvage values of this class of assets.[5] As the samples contain all the discarded machines it further reduces the worries that the assets should all be lemons.

Machine tools is in several respects an ideal category to study the valuation of used capital assets. First, one generally expects that machine tools are assets with relatively little specificity for which there exist well functioning second-hand markets. Second, the capital units are comparatively small, salvage values observable, and the asset age can be determined, in contrast to larger production units (plants or production lines) that are in general a combination of different assets of widely varying age. The data sets contain information on the year the machine was bought and when it was discarded, and the nominal initial price and

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[4] In the 1960 sample the two subsidiaries to Bofors AB (Nydqvist & Holm AB and Ulvsunda Verkstäder AB) stopped producing artillery and concentrated on their other lines of business prior to the sample period. Two firms in the 1990 sample, Asea Robotics and ABB Drives, are related to the 1987 merger between Asea AB and BBC Brown Boveri Ltd, that formed ABB Asea Brown Boveri. The assets discarded by Asea Robotics are from the years before the merger, and the operations of ABB Drives were affected only to a limited extent by the merger.

[5] Some statistics about life lengths for various metalworking machines reveal that they are not too different. Wallander (1962) estimate the average economic life lengths for lathes, drilling-machines, milling cutters and presses to 22, 29, 26 and 28 years respectively. Prais (1986) reaches a similar conclusion.

salvage value (if any). The salvage value of scrapped machines has been set to zero, which is an approximation. Any bias this may cause is likely to be small as scrap values are insignificant and not even recorded separately in firms' own accounting. It is important to note that observed prices are nominal and therefore need to be corrected for inflation. Previous studies have dealt with this problem in a number of ways. Beidleman (1973) uses price indices to deflate and Hulten and Wykoff (1981) have sufficient observations to permit a trend variable account for inflation. In this study we deflate the nominal prices in both samples with a price index for ready-made goods in mining and manufacturing industries (from Statistical Abstracts of Sweden). Clearly such index is not ideal to compare prices over time as it is unclear exactly how it corrects for capital embodied technological progress. I have compared the used index with other price indices published by Statistics Sweden. Two alternative indices are ISIC 382 (non-electrical machinery), available from 1974, and ISIC 3821 (machine tools), beginning in 1980. The choice of deflator does not appear to alter any of the main results as both levels and growth rates of the different indices are very similar. As a robustness check, I assume that the growth rate of the used deflator is systematically too high or too low, as described below.

Tables IIa and IIb give summary statistics of the two samples. The variables are the age of the asset when discarded, denoted AGE, the deflated price of the asset as new, BUY, the deflated salvage value, SELL, and the ratio Q=SELL/BUY.

[TABLES IIa and IIb ABOUT HERE]

There are some immediate observations to be made from Table IIa and IIb. First, large fractions (69 and 38 percent, respectively) of the assets were scrapped rather than sold. Second, the salvage values for sold machines are low (16 and 13 percent of the initial price, respectively). Third, the discarded machines in the 1990 sample are younger those in the 1960 sample. As a comparison, Beidleman (1973) and Oliner (1996) indicate that the service lives are approximately thirty years for this class of assets, but the survey by Oliner suggests that the service lives are falling. Fourth, the average ages of scrapped and sold machines are similar within each firm, but the sold machines were generally more expensive as new. This suggests that machines are not being scrapped because they are obsolete. Instead it is a low initial price that is the key factor in the sell-scrap decision. There are, however, large differences across firms. In the 1990 sample, Asea Robotics discarded young machines that were expensive as new, and was able to sell most of them. Volvo, on the other hand, discarded older pieces with low initial values and scrapped the vast majority. Notably, two firms in the 1960 sample, AB Electrohelios and Ulvsunda AB, which discarded relatively young machines, were able to sell all of them. These patterns are what one expects from Figure I; young assets with high initial values are more likely to have some alternative use outside the firm and can therefore be sold. Few of the assets were discarded at very young age, in particular in the 1960 sample. Figure II shows the fraction sold assets, and the average Q, for the 1990 sample. For later reference it is useful to note that in the 1990 sample 22 were scrapped within five years of purchase at an average age of 2.7 years. The average age of the 19 sold pieces of machinery is 3.5 years and the mean of Q was 0.44. A total of 101 machines were discarded between six and ten years of age (61 scrapped with an average age of 8.5 years, and 40 sold with an average age of 8.1 years and the mean of Q equal to 0.17).

[FIGURE II ABOUT HERE]

As the sample of firms is small and was selected by the researcher it raises the question of the representativness of the sample. To check if the 1990 sample of firms is representative of manufacturing industries (ISIC 38) I conducted a survey of roughly one hundred firms and asked how many machines they scrapped and sold, and their average age, in the years 1990 and 1991. Descriptive statistics from the 38 firms that responded is presented in Table III. The general conclusion is that the 1990 sample is comparable with the results of the survey. For example, in the survey the average ages of sold and scrapped machines are 11-15 and 12-18 years, respectively, which is about the same as the sample averages 13.8 and 18.4. The firms in the survey with 500-1000 employees sell on average 30 percent of the assets compared to 48 percent in the sample (Asea Robotics and ABB Drives). The corresponding numbers for the largest firms are 8-15 percent in the survey and 17 percent in the sample (Volvo Olofström and Saab Flygdivision).[6] Although the firms in the survey are also selected from the total population it is comforting that the simple summary statistics corresponds quite well to the 1990 sample.

[TABLE III ABOUT HERE]

III. Econometric specification

Estimating value-age profiles from prices paid in second-hand markets raises some econometric issues. First, the observed salvage values are always non-negative. It is reasonable to assume that the scrapped assets would fetch prices values lower than costs associated with offering them on the second-hand market. The sold assets, on the other hand, have salvage value sufficiently high to motivate the costs. These observations suggest that the salvage value can be treated as a latent variable in a standard Tobit model. A second issue involved in using transaction prices from second-hand markets arise if the sold assets (i.e. those that actually enter the second-hand market) are biased sample of all assets.[7] For example, if the high quality assets are sold outside the regular second-hand market and the ones that appear there are "lemons", then prices from the second-hand market are downward

[6] Why would large firms scrap relatively more machinery than smaller firms? It could be that small firms employ less specific equipment, or it could be that they pay more attention to selling discarded machinery. On the basis of the current information it is not possible to distinguish between the explanations. However, interviews with firms in the 1990 sample as well as other firms suggests that small firms spend more effort in selling discarded machinery, and may keep discarded machinery for up to a year waiting for a buyer. Large firms, on the other hand, were said to be less patient with unused machinery.

[7] There have been some attempts to correct for this bias in previous studies. Hulten and Wykoff (1981) suggest that each transaction price is multiplied with the probability that the asset has survived until it is observed on the second-hand market to give the expected value for an average asset. However, these probabilities can not be estimated from within the sample and are therefore drawn from survival distributions of similar assets.

biased. Or vice versa, second-hand market prices would be upward biased if the "lemons" were of such obviously inferior quality that they could never be sold. In the present sample, non-randomness of the sample is not an issue as all discarded assets are included. The third, which has been the focus of several earlier studies, is to find a flexible functional form to discriminate between different depreciation patterns.[8] For example, the value-age profile could either be that an asset loses a fixed fraction of the initial value each year (linear depreciation) or a fixed fraction of the remaining value (log-linear depreciation). None of the commonly suggested value-age profiles is consistent with the key features of the data at hand: young assets have low salvage values and often scrapped. Coupled with the econometric complexity in estimating fully flexible specifications in Tobit models and the small sample size, I choose a specific form for the value-age profile, as described below.

The Tobit specification is based on the latent salvage value being described by $SELL_t^* = \beta X_t + e_t$ where the error term, *e*, is normally distributed. In the data $SELL_t = SELL_t^*$ if $SELL_t^* > 0$ and $SELL_t = 0$ otherwise. In the general formulation, each firm may have its own salvage value function in the pooled regression[9]

$$\begin{aligned} SELL_t^* = & \sum_{i=1}^{N} \beta_{0i} FIRMi_t + \sum_{i=1}^{N} \beta_{1i} FIRMi_t * BUY_t + \\ & \sum_{i=1}^{N} \beta_{2i} FIRMi_t * AGE_t * BUY_t + \sum_{i=1}^{N} \beta_{3i} FIRMi_t * AGE_t^2 * BUY_t + e_t \, . \end{aligned} \qquad (1)$$

The dummy variable FIRMi (for i=1..N with N=4 and N=6 in the 1990 sample and 1960 sample, respectively) takes the value one if the discarded asset was owned by firm i. Pooling firms in one regression permits likelihood ratio tests of restrictions on the β_0´s , β_1´s, β_2´s, and

[8] Box-Cox transformations have been used in studies following Hulten and Wykoff (1981) but it has later been demonstrated that the original maximum likelihood estimator suffers from several problems (e.g., Berndt et al, 1993).

[9] In Asplund (1995) the regressions were based on a specification where both sides of (1) were normalised by BUY. The dependent variable was SELL/BUY with a constant, AGE, and AGE^2 as explanatory variables. The results were in line with those reported here.

β_3´s to test for equality of value-age profiles across firms. The regression without firm specific coefficients will serve as a benchmark of the sunk cost component.

The coefficient of primary interest is β_1, which provides an estimate of the fraction of the initial value that can be recouped for a new asset. Under the assumption of efficient second-hand markets and flexible capital β_1 will be close to unity and β_0 close to zero. The variables AGE*BUY and AGE^2*BUY capture the shape of the value-age profiles. The prior is a convex pattern, such that β_2 is negative and β_3 is positive. To add flexibility to the estimated value-age profiles I define two dummy variables D(AGE≤3) and D(4≤AGE≤6) which are interacted with BUY. These variables attempt to capture if young pieces have salvage values higher than suggested by β_2 and β_3. The small sample sizes set some limitations on which coefficients that can be estimated. First, D(.)*BUY can not be estimated together with firm specific coefficients. Second, it is not meaningful to estimate β_3´s or coefficients of D(.)*BUY for the 1960 sample due to the high average age of the assets. Finally, in the 1990 sample, Saab Flygdivision is excluded from the regression analysis as it sold only six machines.

The error term, *e*, for assets from firm i is assumed to be normally distributed with standard error σ_i, such that in the pooled regression the error term is groupwise heteroskedastic. In addition, preliminary regressions showed that the error terms were heteroskedastic with respect to the asset's initial value. The parameterisation of the error term is

$$\sigma_t = \sigma \exp\left(\sum_{i=1}^{N-1} \gamma_i FIRMi_t + \delta \ln(BUY_t)\right). \qquad (2)$$

IV. Results

The results reported in Table IVa generally support the claim that salvage values are low in the 1990 sample. However, there are statistically significant differences in the value-age profiles across firms. The pooling restriction (all firm specific β_0´s, β_1´s, β_2´s, and β_3´s are equal) can be rejected; the likelihood ratio test statistic is 31.2 and the critical value at the 5 percent level with eight restrictions is 18.3. Likewise, it can be rejected at the 5 percent level that the β_0´s are equal (the test statistic is 9.0 and the critical level is 5.99 with two restrictions). At the 10 percent level, the β_1´s and β_3´s differs across firms (although it can not be rejected that β_2´s are equal). Nevertheless, to give the broad picture of the value-age profiles I begin by examine the regressions where the across firm differences are ignored, and then proceed by providing the lower and upper ranges of salvage values for the different firms. The numerical examples are evaluated at the median BUY of the sold machines reported in Table IIa for each firm, respectively. Two expected salvage values are discussed: the latent salvage value, $E\left[SELL_t^* \middle| X_t\right] = \beta X_t$, and the unconditional salvage value, $E\left[SELL_t \middle| X_t\right] = \Phi(\beta X_t / \sigma_t)(\beta X_t + \sigma_t \phi(\beta X_t / \sigma_t) / \Phi(\beta X_t / \sigma_t))$ where $\phi(.)$ and $\Phi(.)$ are the standard normal density and cumulative density function, respectively.

If capital is flexible and second-hand markets efficient then the salvage value at AGE=0 will be close to BUY (the initial owner gets the money back for a newly installed asset). With some examples it can be shown that this does not hold for the assets in question. The first two columns report the pooled regression without any firm specific coefficients.[10] The coefficient on BUY in the first column is 0.357 and the constant term is negative. For a new machine the results in the second column are almost identical; BUY has a coefficient of 0.195 to which one adds 0.159 from D(AGE≤3)*BUY. Hence the expected latent salvage value of a machine of AGE=0 is less than 40 percent of the initial price. The value would be even lower for machinery with low initial price, where the negative intercept is of greater importance. The differences across firms are shown in the third-fifth columns. The coefficients on BUY are all statistically significantly different from one and range from 0.286 (for ABB Drives) to 0.517 (Asea Robotics). The intercepts are all negative which implies that the expected latent salvage value of an asset with AGE=0 is at most 51.7 percent of the initial value. The corresponding latent salvage values at the median BUY gives estimates of

[10] The Tobit regression without heteroskedacity is:

SELL*=-24.3 + 0.378*BUY-0.0269*AGE*BUY+0.0005* AGE^2*BUY with σ=25.7 and LogL=-713.0.

The underlying probit regression for the sell or scrap decision is:

SELLPOSITIVE=-0.745 + 0.0123*BUY-0.000830*AGE*BUY+0.0000144* AGE^2*BUY with LogL=-220.7.

E[SELL*]/BUY between 0.18 and 0.49. The expected latent salvage values would be even lower if the evaluations were based on assets with lower initial values, as the intercepts are all negative. Moreover, the latent salvage value overstates what the firm can expect to get, as it does not account for the probability that the asset is scrapped rather than sold. However, at AGE=0 and the medians of BUY the probability that the assets are sold is close to one such that the latent and unconditional salvage values are almost the same.

The only study, of which I am aware, to compare the results with is by Ramey and Shapiro (1998).[11] Their sample consisted of equipment from closed U.S. aerospace plants that were sold at public auctions or through private negotiations. Most of the assets were machine tools similar to the ones in this study (such as milling machines and lathes), and all 127 units were sold. However, their main results support the basic conclusion here - salvage values are very low. The implied salvage value at AGE=0 for the median machine tool was approximately 50 percent of the initial value, although there were some differences depending on buyer characteristics.

The coefficients on AGE*BUY are negative and AGE^2*BUY positive. Hence, the value-age profile is convex which is consistent with results from previous works. Hulten and Wykoff (1981 p. 106) summarise the results of earlier studies as "even though methods do vary across studies, the general conclusion which emerges is that the age-price patterns of various assets have a convex shape”. As the asset ages the probability that it is sold falls and the difference between the latent and the unconditional salvage values becomes more pronounced. Increasing the age from five years to ten years results in a drop in the probability that the asset is sold rather than scrapped from 0.71 to 0.30 (ABB Drives) and from 0.99 to 0.95 (Asea Robotics). This corresponds to a fall in the unconditional salvage values, E[SELL]/BUY, from 0.06 to 0.02 and from 0.24 to 0.09. Thus after five years the two firms can only expect to get 24 and 6 percent back, respectively, of the initial value.

[11] The studies by e.g. Beidleman (1973), Hulten and Wykoff (1981) and Oliner (1996) are not directly comparable since they do not consider the loss of value during the first year.

An important point to note is that the predictions of salvage values at AGE=0 are out of sample forecasts as there are no assets being discarded immediately and relatively few are scrapped at low age. This calls for some caution before interpreting the numbers as the fraction of a capital investment that is sunk cost. Going back to the descriptive statistics in Section II it is possible to compare the econometric results with salvage values of the assets discarded before five years of age. In the 1990 sample about half of them were scrapped and thus had zero salvage value whereas the sold ones had an average ratio of SELL to BUY of 0.44. This is in line with the numerical examples. Coupled with the very low point estimates it strongly suggests that the sunk cost component is substantial.

Comparing the examples above with the results for the 1960 sample reported in Table IVb reveal broad similarities in estimated salvage values. The coefficients on BUY range between 0.104 and 0.439 and all intercepts (except for one of the firms) are negative. It can be firmly rejected that the β_0´s and β_1´s, respectively, are equal. Out of sample predictions of salvage values near AGE=0 are more uncertain than in the 1990 sample since most assets were discarded at old age and no β_3´s were estimated (the latent salvage value is linear in age).

One may speculate on why there are significant differences in value-age profiles across firms in both samples. All three firms producing machine tools (Asea, Köpings Mekaniska, and Ulvsunda) in the 1960 sample have higher β_1´s than the others. This suggests that there is unobservable specificity in capital that is related to the line of production. For example, even though all firms are using lathes the firms producing machine tools may use a more general type of lathes than a firm who makes water turbines (Nydqvist & Holm). To explore this issue further one needs detailed information on the characteristics on each discarded machine from a large number of firms, something that is not available in the present data set.

The assets were discarded in different years and one may therefore conjecture that salvage values differ. For example, if some assets are discarded during a recession there may be few buyers, Shleifer and Vishny (1992). Conversely, assets discarded in booms may fetch high prices. The sample size is too small to make formal tests of the hypothesis. However, a simple, albeit not powerful, test is to calculate the residuals from the reported regression and group these according to the year the asset was discarded. Under the hypothesis that there are year effects, the assets discarded during boom years should on average have positive residuals (the actual salvage values are higher than the predicted) and vice versa for those discarded in recessions. This simple test gave essentially no support for the prediction.[12] Furthermore, there is some evidence from Table III that suggest that a recession does not lead to dramatic changes. After a period with high growth Sweden falls into a sharp recession in late 1990 with falling real GDP in 1991. Despite this it is difficult to discern any marked shift in scrapping behaviour from 1990 to 1991. However, as the survey does not include information on salvage values it is not possible to reject the hypothesis that there was a shift in the *prices paid* for used assets.

Finally, as noted in Section II, the nominal prices were deflated by the price index for ready-made goods in mining and manufacturing industries. One might worry that such deflator distorts the estimated value-age profiles in a systematic way.[13] As a robustness check of the results, BUY was multiplied by a factor exp(z*AGE), which was substituted for BUY in (1) and (2) in the 1990 sample. Overall, the coefficients were only marginally affected by varying z over a reasonable range. Letting z=-0.03, which corresponds to the case where the

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[12] The residuals from (1) were normalised with BUY (to make the residuals scale invariant) and grouped according to the year the asset was discarded. For the years 1985, 1987 and 1989 the means (-0.087, -0.042 and -0.020) were found to be significantly negative at the 5 percent level by t-tests. However, 1985 and 1989 were years of high growth rates in the economy as well as in the sector when one would expect to find positive residuals. The mean was positive (but not statistically significant) for 1986, which had the lowest growth rate. An alternative specification of (1), which included with year specific coefficients on BUY, gave only one significant coefficient (negative for 1987). Again, the power of the test is limited by the small sample size.

[13] To illustrate the problem, assume that an asset is bought in year 0 at the nominal price 2 and is sold in year 10 at the nominal price 1, such that the ratio of the nominal salvage price to the nominal initial price is 0.5. Further, the deflator used is 50 in year 0 and 100 in year 10, which gives a ratio SELL/BUY of 0.25 (=1/100/2/50). If the true deflator in year 0 is 75 (rather than 50) then the true ratio is 0.375. This implies that the fall in salvage value over the ten-year period, as measured by SELL/BUY, is greater than the true. This problem would be exacerbated for older assets if the deflator systematically (every year) overestimates the general change in prices.

used deflator is systematically three percent too high, gave slightly higher point estimates of β_0´s, β_1´s and β_3´s and lower β_2´s, while the reverse holds for z=0.03. The coefficients for ABB Drives were the most influenced (β_1 varied between 0.21 (z=0.03) and 0.37 (z=-0.03) compared to 0.28 in the reported regression) but none of the results were qualitatively different. The conclusion from this exercise is that the low point estimates of β_1´s are not due to the deflator.

[TABLES IVa and IVb ABOUT HERE)]

V. Concluding remarks

The main finding of this study is that capital investments in metalworking machinery (machine tools) appear to be largely sunk costs. This is supported firstly by the fact that in the most recent sample as much as 69 percent of the machine tools were scrapped rather than sold. Additional survey evidence from Swedish manufacturing firms indicates that these numbers are not unique to the firms in the sample. Secondly, the econometric results showed that the expected salvage value of an average "new" machine, conditional on it being sold, is at most only about 50 percent of its initial price. The percentage is even lower for the unconditional expected salvage values, where we take into account that many machines are scrapped rather than sold. The regressions suggest that the sunk cost component range between 50-80 percent for investments in machine tools. These figures are higher than one would expect for this class of assets, and undoubtedly much higher than for assets like aircraft, oil tankers, and office buildings.

It was argued that the sample of firms is representative for firms operating in Swedish manufacturing industries and that the assets were not discarded in years with unusually low demand. Neither could the low salvage be dismissed as a consequence of excessive deflation of the nominal prices nor reflecting values of low quality assets (lemons). The primary alternative explanation is instead that even though these assets were believed to be general-purpose equipment they are, in fact, not. A specific asset may either have few potential buyers or is costly to rebuild to fit new applications. This would then result in the observed situation where many assets are scrapped, and prices for sold pieces are low. Given that it is costly to search for buyers one might conjecture that salvage values are higher in large divestments where assets can be sold at public auctions. The present sample of machines that were discarded piecemeal would then underestimate what a firm gets if it sells all its capital. Additional research is needed to compare the salvage values estimated in this paper with those at large divestments. An important first step in this direction is Ramey and Shapiro's (1998) study of equipment (primarily metalworking machinery) that were sold following plant closures in the U.S. aerospace industry. Their estimate of the salvage value of a "new" machine tool is around 50 percent of its initial value. Although this is somewhat higher than the results reported here it is, nevertheless, very low. Hence their results support the explanation that the capital assets in question are specific and therefore largely sunk costs.

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Table I. Description of the firms in the samples.

Firm name	Line(s) of production	Revenue in SEK (Year)	Year: Number of discarded machines	Other information
Asea Robotics	Industrial robots	~0.9 billion (1986)	83:5, 84:15, 85:24, 86:9	Subsidiary of Asea.
ABB Drives	Rolling mills, equipment for mining and pulp and paper industry	~1.0 billion (1990)	86:19, 87:28, 88:29, 89:24, 90:25	Subsidary of ABB Asea Brown Boveri Ltd
Volvo (in Olofström)	Car parts (some truck parts)	~2.5 billion (1990)	89:192, 90:91	Part of Volvo Passenger Cars
Saab Flygdivision	Aircraft parts	~4.3 billion (1990)	89:18, 90:28	Subsidiary of Saab-Scania
AB Elektrohelios, Stockholm	Electromechanical products, ovens	92.6 million (1959)	55:1, 56:5, 57:8, 58:3, 59:1	Subsidiary of Asea.
Asea (divisions in Västerås)	Machine tools, motors, transformers	~650 million (1959)	54:4, 55:17, 56:24, 57:36, 58:22, 59:22	Excluding Asea divisions outside Västerås.
Nydqvist & Holm AB	Water turbines, engines, (previously artillery)	70.1 million (1959)	54:15, 55:30, 56:18, 57:28, 58:27	Subsidiary of Bofors AB.
AGA (in Lidingö)	Equipment for lighthouses, traffic lights, radiators	129 million (1959)	54:10, 55:1, 56:12, 57:14, 58:28, 59:30	Excluding the division producing TV-sets.
Köpings Mekaniska Verkstad AB	Machine tools	21.9 million (1959)	54:1, 55:4, 56:10, 57:5, 58:8, 59:9	Subsidiary of Volvo.
Ulvsunda Verkstäder AB	Machine tools, (previously artillery)	9.7 million (1959)	54:2, 55:4, 56:9, 57:2	Subsidiary of Bofors AB.

Notes: In January 1959 USD 1 = SEK 5.2 and in January 1990 USD 1= SEK 6.6. The consumer price index, with base year 1959, was 561 in 1990. The revenue figures are based on information in annual reports where a '~' denotes that the figure has been estimated by the author.

Table IIa. Descriptive statistics for 1990 sample.

		Sold				Scrapped			
FIRM	Variable	Mean	St.Dev	Median	Nobs	Mean	St.Dev	Median	Nobs
Asea	BUY	443	641	213	39	110	54.8	115	14
Robotics	SELL	62.9	79.1	45.2	39				
	Q	0.237	0.184	0.161	39				
	AGE	8.44	4.30	7.0	39	7.36	3.10	8.0	14
ABB	BUY	94.3	190	36.7	42	32.0	58.4	11.1	64
Drives	SELL	8.08	17.5	2.25	42				
	Q	0.142	0.330	0.0637	42				
	AGE	13.2	8.04	12.0	42	14.9	9.44	15.0	64
Volvo	BUY	64.6	94.3	56.1	49	37.2	97.7	13.9	192
Olofström	SELL	5.83	13.7	3.40	49				
	Q	0.0916	0.136	0.0576	49				
	AGE	18.8	8.66	18.0	49	19.7	9.18	18.0	192
Saab	BUY	183	387	14.3	6	93.0	110	61.8	38
Flygdivision	SELL	16.1	28.4	4.33	6				
	Q	0.257	0.237	0.205	6				
	AGE	12.7	4.13	13.0	6	21.6	7.95	21.0	38

Table IIb. Descriptive statistics for 1960 sample.

		Sold				Scrapped			
FIRM	Variable	Mean	St.Dev	Median	Nobs	Mean	St.Dev	Median	Nobs
AB	BUY	11.1	9.13	6.52	18				0
Elektrohelios	SELL	2.44	2.70	1.36	18				
	Q	0.217	0.137	0.215	18				
	AGE	17.4	9.09	15.5	18				0
Asea	BUY	35.1	29.6	22.9	40	25.1	30.8	13.4	56
Västerås	SELL	6.66	17.0	2.50	40				
	Q	0.171	0.270	0.127	40				
	AGE	24.1	9.82	23.5	40	23.7	10.8	22.0	56
Nydquist &	BUY	52.2	56.4	37.9	78	39.6	44.1	21.0	24
Holm AB	SELL	3.49	5.16	1.87	78				
	Q	0.0762	0.0708	0.0564	78				
	AGE	24.5	12.6	21.0	78	29.5	13.7	32.0	24
AGA	BUY	14.8	9.21	14.6	42	13.3	8.82	11.8	34
Lidingö	SELL	1.23	2.54	0.507	42				
	Q	0.0796	0.113	0.0357	42				
	AGE	33.3	12.1	38.5	42	34.2	11.2	40.5	34
Köpings	BUY	41.5	37.1	44.7	16	16.1	9.32	15.0	17
Mekaniska	SELL	11.6	13.2	6.17	16				
AB	Q	0.313	0.328	0.171	16				
	AGE	20.4	14.7	16.5	16	21.0	11.5	17.0	17
Ulvsunda AB	BUY	44.3	19.8	42.5	17				0
	SELL	7.81	4.79	7.35	17				
	Q	0.178	0.106	0.186	17				
	AGE	19.5	5.70	22.0	17				0

Table III. Descriptive statistics from survey of 38 Swedish manufacturing firms. (Standard deviation in parenthesis.)

Year	1990	1990	1990	1991	1991	1991
No. of employed in 1991	<500	500-1000	>1000	<500	500-1000	>1000
No. of firms	11	14	13	11	14	13
No. of sold machines	89	194	355	48	379	518
	(9.9)	(13)	(21)	(11)	(28)	(44)
Average age	11.2	15.7	9.5	11.0	15.1	10.9
	(6.8)	(5.4)	(4.4)	(3.5)	(6.0)	(5.3)
No. of scrapped machines	98	467	~4200[a)]	75	773	~2900[a)]
	(11)	(44)	(~503)	(16)	(73)	(~290)
Average age	14.2	18.3	12.1	10.9	15.5	12.0
	(6.7)	(4.2)	(4.4)	(4.6)	(6.6)	(4.0)

a) For the firms with >1000 employed the numbers are approximate, as indicated in survey responses.

TABLE IVa. Results from Tobit regression on 1990 sample.
Dependent variable is SELL. (Standard errors in parenthesis.)

Coefficient	No firm specific coefficients [a)]	No firm specific coefficients[b)]	Asea Robotics [c)]	ABB Drives [c)]	Volvo Olofström [c)]
CONSTANT (β_0)	-5.28*** (0.688)	-5.23*** (0.651)	-5.68 (4.56)	-3.75*** (0.904)	-8.25*** (1.41)
BUY (β_1)	0.357*** (0.0371)	0.195*** (0.0621)	0.517*** (0.141)	0.286*** (0.0828)	0.302*** (0.0652)
AGE*BUY (β_2)	-0.0312*** (0.00472)	-0.0143*** (0.00670)	-0.0592* (0.0349)	-0.0322*** (0.00915)	-0.0267*** (0.00730)
AGE^2*BUY (β_3)	0.000593*** (0.000142)	0.000237 (0.000191)	0.00189 (0.00208)	0.000966*** (0.000245)	0.000525*** (0.000174)
D(AGE≤3)* BUY		0.159** (0.0619)			
D(4≤AGE≤6)* BUY		0.149*** (0.0379)			
γ			0.586*** (0.192)	-0.516*** (0.186)	≡0
NOBS	400	400	53	106	241

***, **, and * denotes statistical significance at 1, 5, and 10 percent level.
a) LogL= -634.0, σ=1.24*** (0.151) and δ=0.581*** (0.0333).
b) LogL= -628.0, σ=1.23*** (0.143) and δ=0.572*** (0.0318).
c) LogL = -606.7, σ=2.93*** (0.832) and δ=0.336*** (0.0614).
Restricted ($\beta_{0i}=\beta_{0j}$ & $\beta_{1i}=\beta_{1j}$ & $\beta_{2i}=\beta_{2j}$ & $\beta_{3i}=\beta_{3j}$ for $\forall$ i, j) LogL = -622.3
Restricted ($\beta_{0i}=\beta_{0j}$ for $\forall$ i, j) LogL = -611.2
Restricted ($\beta_{1i}=\beta_{1j}$ for $\forall$ i, j) LogL = -609.4
Restricted ($\beta_{2i}=\beta_{3j}$ for $\forall$ i, j) LogL = -608.4
Restricted ($\beta_{3i}=\beta_{2j}$ for $\forall$ i, j) LogL = -609.4

TABLE IVb. Results from Tobit regression on 1960 sample.
Dependent variable is SELL. (Standard errors in parenthesis.)

Coefficient	Electro-Helios [a)]	Asea Västerås [a)]	Nydquist & Holm [a)]	AGA Lidingö [a)]	Köpings Mekaniska [a)]	Ulvsunda Verkstäder [a)]
CONSTANT	0.649	-3.11***	-0.324*	-0.0714	-2.53	-0.167
(β_0)	(0.583)	(1.03)	(0.171)	(0.286)	(1.70)	(1.29)
BUY	0.170**	0.285**	0.136***	0.104*	0.326*	0.439***
(β_1)	(0.0777)	(0.139)	(0.0179)	(0.0561)	(0.186)	(0.0631)
AGE*BUY	-0.00248	-0.00778	-0.00297***	-0.00302**	-0.00869	-0.0131***
(β_2)	(0.00471)	(0.00521)	(0.000519)	(0.00150)	(0.00660)	(0.00298)
γ	-0.509	1.54***	0.0776	0.596***	1.77***	$\equiv 0$
	(0.335)	(0.213)	(0.219)	(0.230)	(0.304)	
NOBS	18	96	102	76	33	17

***, **, and * denotes statistical significance at 1, 5, and 10 percent level.
a) Unrestricted LogL = -619.4, σ=0.0837*** (0.0277) and δ=0.945*** (0.0714).
Restricted ($\beta_{0i}=\beta_{0j}$ & $\beta_{1i}=\beta_{1j}$ & $\beta_{2i}=\beta_{2j}$ for $\forall$ i, j) LogL = -658.2
Restricted ($\beta_{0i}=\beta_{0j}$ for $\forall$ i, j) LogL = -629.6
Restricted ($\beta_{1i}=\beta_{1j}$ for $\forall$ i, j) LogL = -628.2
Restricted ($\beta_{2i}=\beta_{3j}$ for $\forall$ i, j) LogL = -624.6

Figure I. The initial owner's and the best secondary user's valuation of an asset as a function of its age.