FIRM EXIT, VINTAGE EFFECT AND THE BUSINESS CYCLE IN NORWAY

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Abstract: In spite of the large and growing literature on producer heterogeneity and firm exit behavior, little attention has been paid to the vintage capital theory of firm exits as an alternative hypothesis to learning/selection. Interpreted at the firm level the vintage capital theory predicts that exit rates increase in the age of capital. The present paper uses a panel of Norwegian manufacturing plants and constructs an index of capital age in addition to the age of the establishment in order to disentangle the effects of selection/learning and vintage capital on exit rates. The empirical results suggest a U-shaped exit function in the age of the plant implying both a learning effect and a vintage capital effect. The vintage capital effect is present under different assumption concerning reinvestments and controlling for unobserved heterogeneity. The exit rates are found to depend on the business cycle in that exits increase in a severe downturn. Our results also support the assertion that recessions are periods of cleansing where old capital equipment is scrapped via exiting plants.

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1. Introduction

A well-established stylised fact is that massive flows of factors of production is a continuous process and well above what is necessary to accommodate the net changes for an economy.[1] It is also established that to a large extent these changes - for instance measured as newly created and destructed jobs - are permanent changes. Hence, modernisation or restructuring is taking place via a continuous process of entry and exit of plants and growth and reduction of incumbents. Theories emphasising producer heterogeneity via learning processes and market selection are developed and tested empirically to explain these observations. One hypothesis in particular has gained strong empirical support; young plants have higher exit rates than old plants.[2] This result is in accordance with theories of active and passive learning processes such as models by Jovanovic (1982) and Pakes and Ericson (1992), predicting that young establishments should have a lower survival rate, where plant age is a proxy for the productivity.

In spite of the large literature on producer heterogeneity and firm exit behaviour little attention has been paid to the capital vintage theory of firm exit behaviour as an alternative hypothesis (see Johansen, 1959, 1972, Førsund and Hjalmarsson, 1991, Solow, 1956, 1960, Greenwood and Jovanovich, 1998). Interpreted at the firm level this theory predicts that plants with old vintages of capital – a proxy for low efficiency - have higher exit rates than plants with more recent vintages of capital. However, it is not clear how strong the vintage effect is in determining exit rates. Through investments old plants may acquire the most recent technologies or new cohorts of plants may invest in old vintages of capital. For instance, for the US manufacturing little empirical support for a high correlation between capital age and plant age has been found, cf. Dunne (1994).

The main aim of the present paper is to disentangle the distinct effects of selection and

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1 See for instance Geroski (1991) and a special issue of International Journal of Industrial Organization (Vol. 13 No. 4, 1995) on plant turnover and growth pattern of firms. The other strand of literature is the recent work on gross job flows. Important contributions are Leonard (1987), Dunne, Roberts and Samuelson (1989), Davis and Haltiwanger (1990; 1992), Blanchard and Diamond (1990), Boeri and Cramer (1992). See Klette and Mathiassen (1996a) and Salvanes (1997) on the effects of job turnover in Norway, and Salvanes and Førre (1998) for turnover by worker categories.

2 See Evans (1987), Dunne, Roberts and Samuleson (1989), Boeri and Bellmann (1995), Doms, Dunne and Roberts (1995), Audretch and Mahmood (1995), Mata and Portugal (1997). See in particular Klette and Mathiassen (1996b, chapter 6) for an analysis on the effect of plant age and productivity for the Norwegian manufacturing sector for the period 1976-86.

vintage capital on exit rates by using a machine capital age index in addition to the age of the plant. A panel of Norwegian manufacturing establishment level data from 1976 to 1992 is used. Our hypothesis is that both effects occur, predicting a U-shaped pattern of exit rates in the age of the establishment. The failure rate is first expected to decrease in plant age due to selection and/or learning effects, and then to increase due to the vintage capital effect. Further, little attention has been paid so far in the empirical IO-literature on exit behaviour to the panel structure of establishment observations. In the empirical literature the exit rates estimated as a function of firm age are conditioned on other observable variables such type of industry, the degree of industry competition etc., but unobserved variables may also be correlated with included variables causing biased results. Since we have a panel data set we are able to incorporate the unobserved relationship of firms over time by including random effects in the exit model as well as testing the stability of the results by including observable variables in addition to establishment age and capital age. In order to test how the strength of the vintage effect might depend on market conditions, we test a prediction from Lambson's (1991) model. His model predicts a weak vintage effect in industries characterised by low sunk costs in that entering firms will choose both standard and advanced technologies and thus a variability in exit rates is expected while in industries with high sunk costs producers are expected to choose the same technology.

Secondly, the paper contributes to the controversial point of whether restructuring is clustered in downturns via a "shake-out" effect on plants or a "cleansing" effect. A central part of models of "cleansing" in recessions is the capital vintage model where a Schumpeterian creative destruction process occurs involving the exit of old plants with outdated technology (see for instance Blanchard and Diamond, 1990; Caballero and Hammour, 1994, 1996). The second element is that these theories predict a tendency to reduce during recessions due to for instance changing opportunity costs of restructuring over the business. The empirical evidence on counter-cyclical restructuring is mixed. In the job turnover literature a counter-cyclical pattern for job destruction including both job reduction and exit of plants are found for some countries but not for others.[3] Few micro level studies exist on the relationship between survival

3 In particular, studies from North-America show that job turnover is counter-cyclical (Davis and Haltiwanger, 1990, 1992). For the UK and the Netherlands counter-cyclical job turnover have been found for large firms (Konings, 1995, Broersma and Gautier, 1995). For Danish manufacturing in the period 1980-91 the pattern is acyclical (Albæk and Sørensen, 1998). Boeri (1996) compares seven OECD countries – including Norway - and finds limited support for counter-cyclical job turnover in Europe.

and growth of plants and aggregate fluctuations. In a study by Boeri and Bellmann (1995) using a panel of German manufacturing plants for the period 1979-1992, no relationship is found between exit rates and cyclical fluctuations. We test whether the exit probability is counter-cyclical using different proxies for the business cycle and distinguishing between a minor and a major slump. Further, by incorporating interaction terms between the business cycle indicator and the vintage of capital and the age of the establishment, we test whether restructuring in downturns is related to the age of establishment or to the age of the capital.

The rest of the paper is as follows. The next section presents the model to be estimated. Section 3 presents the data set and some background information of the Norwegian economy in the data period. In Section 4 the results from the empirical examination of our hypotheses are presented. Section 5 concludes.

2. Theories of plant exit and econometric specification

2.1 Three models of plant exit

The aim of this paper is first to extend the empirical literature on the post entry performance of plants by using a panel of plant data to examine in fuller detail the plant level heterogeneity. Three theories exist for plant exit. The selection model or passive learning model due to Jovanovic (1982) predicts that firms learn about their relative abilities at the date of entry via a selection process of firms. In the second model, active learning or evolutionary learning model, the firms initial ability is not as important as their ability at making progress and reducing the gap between themselves and the incumbents (Pakes and Ericson, 1992). Both these theories predict that the age of the plant as a proxy for productivity reduces the exit rate. The vintage capital model interpreted at the firm level predicts that the age of capital increases the exit rate of firms (Johansen, 1959, 1972; Solow, 1956, 1960). The main point is that new technology is embodied in the latest vintages of capital. Thus new capital is better or more productive than old capital not only because of wear and tear but because new capital was more productive than old capital even when the old capital was new. Most focus in the empirical literature has so far been on testing the effect of plant age on exit probability by including the age of the establishment. The empirical support is strong for higher exit rates for young establishments, cf. Evans (1987), Dunne, Roberts and Samuelson (1989), Boeri and Bellmann (1995), Doms, Dunne and Roberts (1995), Audretsch and Mahmood (1995). The alternative hypothesis of a vintage effect – or in our view a complementary hypotheses in that both plant age and capital vintage influence the probability of exit– has not been tested to any degree.[4] When testing for the vintage effect – for instance in cases of testing models of cleansing effects of downturns – the age of the establishment has been used as a proxy for the vintage of capital due to data limitations (Davis and Haltiwanger (1990) and Caballero and Hammour, 1994, 1996). This presumption probably has poor empirical support, cf. Dunne (1994). Through investments old plants often acquire the most recent technologies. Our hypothesis is that both effects exist simultaneously in an industry. By incorporating both the plants' age and the age of the plants' capital constructed by using investments in machinery based on Mairesse's (1978) approach, we are able to disentangle the distinct effects of selection and vintage capital on exit rates. A U-shaped pattern of exit rates in the age of plants is expected when both forces are active. The failure rate of plants is first expected to decrease in plant age due to the selection or learning effect, and then the exit rate is expected to increase due to the vintage capital effect.

2.2 The cleansing effect of recessions

The next question we examine is whether restructuring via exits is concentrated in downturns, and whether this is via a stronger selection process or via a stronger capital vintage effect. In the empirical IO-literature little attention has been devoted to the relationship between aggregate economic fluctuations and new establishment survival and growth. This can probably partly be explained by the lack of panel data that covers at least one business cycle. Notable exceptions are Audretsch and Mahmood (1995) and Boeri and Bellmann (1995) who analyse the influence of the business cycle on firm survival rates. The latter study also examines the cyclical sensitivity of new firm growth. Audretsch and Mahmood (1995) find that the hazard rate of new firms increases with the unemployment rate, which is used as a proxy for the business cycle. In other words, new firms are more likely to fail during macroeconomic downturns. Boeri and Bellmann (1995), who employ the growth rate of unemployment, find

4 See Johansen (1972) in chapter 9 and Eide (1969) found some support for a vintage effect on the productivity of vessels using data for Norwegian tankers.

that hazard rates of new firms are not responsive to the business cycle. Furthermore, they find that the growth of surviving entrants exhibits little cyclical sensitivity.

Most of the recent focus on downturns as a cleansing period comes from the recent job creation literature. In some of these studies job turnover is found to be counter-cyclical, indicating restructuring in recessions, and the driving force is an asymmetry between job creation and job destruction. Several theories have been proposed to explain the asymmetry between job creation and destruction characterised by concentration of increased by job reductions in recessions. The mechanisms in these models are either asymmetry in labour adjustment costs, or between hiring and firing, the different time it takes to hire and fire, or by a change in the opportunity costs of making changes over the cycle. For instance, if there exists costs associated with establishing or creating a new job but no firing costs, job destruction will be more dependent on a contemporaneous shock than job creation (Davis and Haltiwanger, 1990). Hence, both in upturns and downturns job creation will be slower to adjust and smoothed out over the cycle. Somewhat different is the theory proposed by Mortensen and Pissarides (1994) using a matching model approach. Here job creation takes time in order to establish a successful match. During an upturn when the labour market is tight, it is difficult to fill newly created jobs. During a recession, jobs are destroyed immediately. A third class of models focuses on the differences in opportunity costs in terms of foregone production between a boom and a recession when changes in labour or capital are being made (Blanchard and Diamond, 1990, Caballero and Hammour, 1994, 1996).

Although somewhat different in spirit, these models basically provide explanations for why job turnover and thereby some kind of restructuring, takes place mainly in recessions although high turnover is a continuous process. Some of the models - especially models focusing on low opportunity costs foregone in a recession - have the common feature that a recession is a time of shake-out for industries or that there is a "cleansing" effect of recessions. Notable here is Caballero and Hammour (1994, 1996) who explicitly state this. The empirical results concerning this "cleansing" effect are still scarce. Davis and Haltiwanger (1992), have some support for the shakeout hypothesis in that job reductions are mainly among large and old plants.

2.3 Econometric specification

Based on this discussion we postulate an exit function as follows:

$$EXIT_{it} = f(PLANTAGE_{it}, CAPAGE_{it}, BUSCYCLE_t, \mathbf{X}_{it,}),$$

where subscript *i* refers to plant and subscript *t* refers to the year, *EXIT* is a dummy variable which takes the value one if the plant shuts down, *PLANTAGE* is the age of the plant, *CAPAGE* is the age of the machine capital equipment. Both the age of the establishment and the vintage of capital include second-order terms in order to capture non-linearity of the exit rate in plant age and capital age. *BUSCYCLE* is and index for the business cycle, and *X* is a vector of other determinants of plant exit which is not of primary interest in this study but which nevertheless should be introduced into the model in order to avoid omitted-variables biases in our estimates.

We use Mairesse's (1978) age index measure for the capital equipment:

$$A_t = \left[K_{t0}^V p_v \bar{a}_t^V + I_{t0} p_{t0} (t - t_0) + \ldots + I_{t-1} p_{t-1} (1) \right] / K_t$$

where

$$K_t = K_{t0}^V \bar{p}_v + I_{t0} p_{t0} + I_{t1} p_{t1} + \ldots + I_{t-1} p_{t-1},$$

$$K_t^V = K_t - (I_{t0} + \ldots + I_{t-1}),$$

and, I_t = nominal investments (purchase less sales) in capital equipment, K_t = real stock of capital equipment in period *t*, K_t^V = nominal stock of capital equipment of vintage *V* in period *t*, p_t is the price index in year *t* (the whole sale price index), $\bar{a}_t^V$ is the mean age of capital equipment acquired before t_0, which is the first time period data is available for (i.e., 1977). For plants established prior to 1977 we computed a proxy for $\bar{a}_t^V$ based on aggregate machine capital and investments data in the industry which the plant belonged to (at the 4- and 5-digit SIC level).[5]

The age index definition implies that in year $t = t_0$ the age index $A_t = 1$. If real investments $I_v p_v$ are identical in all years, investments in period *t*-1 will increase the age index A_t more than investments in the subsequent period *t* due to the factor $(t - t_v)$ in the age index equation. We only use the age index for machine capital in our model, as the performance of plants should be less affected by the age of building capital.

5 Statistics Norway supplied industry aggregate investments and capital data.

We employ several different business cycle indicators. The first, GDPGROW, is the percentage change in Norwegian GDP from the previous year, which can be regarded as the standard indicator of the business cycle. Another business cycle indicator we use is the percentage deviation from the GDP trend growth. Using annual real GDP for the period 1973-92 we employed the Hodrick-Prescott (HP) filter to estimate the GDP trend. The motivation for using deviations from the trend is that when decision-makers in firms look at the macro economic environment, they may be more concerned about deviations in GDP growth from the trend than the absolute level of GDP growth. The trend GDP growth is regarded by decision-makers as the 'normal' state. GDP growth below the trend is regarded as deterioration of the general business environment, and *vice versa*. By using a HP filter we imply that decision-makers gradually adjust their perception of what is the normal GDP growth rate, i.e. when the business environment is neither improving nor deteriorating. For the smoothness parameter of the HP filter, λ, we chose the value 16. Other values of λ were also tried, but these produced trends that sometimes exhibited kinks.

An alternative to the above business cycle indicators is to use dummy variables to represent recessions. In one specification we employ the dummy variable RECESS, which is equal to one in the recession years 1978, 1982-3 and 1988-92. In another specification we differentiate between 'weak' and 'strong' recessions. An argument for distinguishing between a strong and a weak recession in an exit function is that a large shock might be necessary to induce a counter-cyclical pattern in plant turnover via exiting firms. It is well established in the literature that incumbent firms take most of the adjustment associated with business cycle changes, since sunk costs of entry and exit of firms are expected to be larger in most cases to the adjustment costs of incumbent firms, cf. Davis and Haltiwanger (1990) and Caballero and Hammour (1994, 1996). The dummy WEAKRE is employed for the minor recession years (1978 and 1982-3), and the dummy STRONGRE for the years with the deeper recession (1988-92). In order to test for whether old plants or plants with old capital have higher exit rates in slumps, or in large downturns, interaction terms between the business cycle indices and CAPAGE and PLANTAGE are formed.

In order to test the robustness of our basic model including PLANTAGE, CAPAGE and BUSCYCLE, we condition our exit model on a number of other variables which have been found to be important in explaining exit behaviour and which may be correlated with the age of capital and the age of the establishment. The effect of plant size on survival is supposed to be captured by the logarithm of plant employment (*LNEMPL*). A positive correlation between the age of the establishment and the size of the establishment is expected and the size of the establishment should be included to isolate the age effect. Other variables included in X is a Profits/Employees, where Profit = Sales - Wages - Materials (in mill NOK), *PROFEMPL*. Profitability may also easily be correlated with the age of plants and thus should be conditioned upon to obtain the pure age of establishment effect. Industry fixed effects are also controlled for (4 digit ISIC level). As Lambson (1991) shows in his theoretical model of industry evolution, the importance of the vintage effect in an industry depends on characteristics of the industry such as the degree of sunk costs and the relative stability of factor and output prices. We test the hypothesis of expected lower vintage effect on exits with low sunk costs by estimating a separate model for high and low sunk costs industries. The potential impact of plant heterogeneity on estimates is accounted for by including random plant-specific effects in some of the estimated exit models. Other panel data models are rejected due to computational intractability and inconsistency in estimates (Maddala, 1987).

We choose a probit model as the parametric specification of our exit model.[6] The model is given by

$$EXIT_{it}^{*} = b\,\mathbf{x}_{it} + u_{it}, \quad i = 1,2, ..., N, \quad t = 1,2,..., T,$$

with

$$EXIT_{it} = 1 \text{ if } EXIT_{it}^{*} > 0$$

$$EXIT_{it} = 0 \text{ otherwise,}$$

where u_{it} ~ IN(0, s_u^2). In the probit model the probability that plant *i* will shut down in year *t* is (Maddala, 1983):

$$\begin{aligned}\text{Prob}\left[EXIT_{it} = 1\right] &= \int_{-\infty}^{b'\mathbf{x}_{it}} f(u)du \\ &= \Phi\left(b'\,\mathbf{x}_{it}\right)\end{aligned}.$$

6 The Cox proportional hazards model, which has been applied in several studies recently (Audretsch and Mahmood, 1994, 1995; Mata *et al*., 1995) was considered as an alternative, but was rejected because it does not allow the explicit inclusion of plant age as a determinant of plant survival. In the Cox specification the effect of plant age is captured by the underlying baseline hazard rate, which is not estimated directly (Cox, 1972). The baseline hazard rate can be derived from the estimated Cox model, but it tends to exhibit very erratic patterns.

In words, the probability of exit is equal to the area under the standard normal distribution from -∞ to β'**x**. As the value of β'**x** increases the likelihood of exit also increases.

The random effects probit model is given by:[7]

$$EXIT_{it}^{*} = b\,\mathbf{x}_{it} + a_i + u_{it}, \qquad i = 1,2, ..., N, \;\; t = 1,2,..., T,$$

where $a_i \sim \text{IN}(0,\ s_a^2)$ is the plant-specific effect, and a_i and u_{it} are mutually independent and independent of $\mathbf{x}_{it}$. This leads to a more complicated expression for the density of *EXIT*, see Maddala (1987). Define $s^2 = s_a^2 + s_u^2$ and $r = s_u^2 / s^2$. Furthermore, define $v_{it} = u_{it} / s_u$, $q_i = a_i / s_a$ and $b^* = b / s$. Then

$$EXIT_{it} = 1 \Rightarrow \frac{u_{it}}{s_u} > \frac{-\mathbf{b}'\,\mathbf{x}_{it} - s_a q_i}{s_a}.$$

By defining

$$a_{it} = \frac{-\mathbf{b}^{*\prime}\,\mathbf{x}_{it} - r^{1/2} q_i}{(1-r)^{1/2}},$$

the above condition can be restated as

$$EXIT_{it} = 1 \Rightarrow v_{it} > a_{it},$$

$$EXIT_{it} = 0 \Rightarrow v_{it} \le a_{it}.$$

The joint density of $EXIT_{it}$ is given by

$$\text{Prob}(EXIT_{it}) = \prod_{i=1}^{N} \int_{-\infty}^{\infty} \prod_{t=1}^{T} \left[1 - F(a_{it})\right]^{EXIT_{it}} \left[F(a_{it})\right]^{1-EXIT_{it}} \frac{1}{2p} e^{-q_i^2/2} dq_i,$$

where $F(a_{it})$ is the common degree of freedom of the standard normal.

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7 When the dependent variable is qualitative (e.g. a binary variable) and there are only a few time series observations per individual a fixed effects approach may not give consistent estimates of the slope coefficients, see Andersen (1973) or Chamberlain (1980). For the probit model, in particular, it is not possible to cancel out the fixed effects (i.e. a dummy variable approach is required), and the estimates of the slope coefficients are inconsistent. With a random effects approach the probit model is the computationally tractable alternative for binary dependent variables (Maddala, 1987). The estimates of the probit model with random effects are consistent. However, as in the standard model with a continuous dependent variable it is assumed that the random effect is uncorrelated with the explanatory variables. The pooled probit estimator provides consistent but inefficient estimates in the presence of random effects.

3. Data, variables and preliminary results

3.1 Definitions, data and measurement issues

We have access to a panel of establishments or plants for the Norwegian manufacturing from Statistics Norway, with annual observations, which stretches from 1976 to 1992. The Norwegian manufacturing database is employed in the estimation of the plant exit model (See Halvorsen et al. (1991) for a description of the data set). The plants are observed during the 1977-92 period. All manufacturing establishments with five or more employees in each year are included in our data set, except those where the owner is working alone, and plants under construction. Plants with less than five employees are dropped because they did not report capital and cost figures in the manufacturing survey.

In the database an establishment is defined as a functional unit which at a single physical location is engaged mainly in activities within a specific activity group. Production activities with different street addresses in the same municipality are regarded as distinct establishments. Activities undertaken by two different owners in the same plant are registered as two establishments. Furthermore, activities in different industry groups (3-digit), are classified as separate establishments even if the activity is located at the same site. Information on the number of employees is annual averages, which include all persons - also owners working in the establishment. The stock of machine and building capital is measured by the fire insurance value.

The data set explicitly identifies new establishments, continuing establishments and establishments that are closed down for the years 1977-86 in the so-called «entry-exit» file. Thus, if there for instance are no data for an establishment in 1977, but data for 1978, the data set indicates if the establishment actually started operation this year, or if there were other reasons for missing data in 1977. Similarly, if data are present for an establishment in 1984, but no data are available for 1985, the data set tells us if the establishment actually shut down this year, or if there are other reasons for missing data. Explicit entry-exit information is not available for the 1987-92 period. For these years we have treated a plant as newly established in one year if it was observed in that year but none of the preceding years. Furthermore, if a plant was observed in one year but none of the subsequent years, we treat it as an exit. Use of these procedures on the 1977-86 data where we have exact information on exits, suggests that the absence of entry-exit information in later years does not create any biases for our analysis.

A potential problem for analysis of exits at the establishment level, may be mergers or buy-outs at the enterprise (or firm) level. However, in the Norwegian manufacturing database mergers or change of ownership are not a problem since the plant's identification code is unaffected by such events. Appendix A provides descriptive statistics of all variables used both before and after the reduction of the number of observations because of missing data on some variables.

3.2. Preliminary results: Restructuring and the business cycle in Norway 1976-1992

In order to give an overview of the Norwegian economy in the data period and the degree of restructuring, we first provide some background descriptive statistics of the economic development focusing on the business cycle and the turnover process. The role of plant exit relative to restructuring by incumbent plants in a minor and a major recession is focused on.

In Figure 1a we present plots of the different business cycle indicators.[8] They basically follow the same pattern, and we concentrate the discussion of the time pattern of the net employment change. The data period exhibit a recession in 1982/83 and a boom in 1985/86, a minor recession 1978, and in addition a major recession in the late eighties from 1988. The 1982/83 recession was common to all European countries, as was the boom in the mid-eighties. Two main reasons are important in explaining the particular Norwegian recession in the late eighties. The drop in the oil price in 1987 affected the Norwegian economy as a major oil-producing country, and in addition there was a big crisis in the Norwegian banking sector following a deregulation of the sector in the mid eighties. There exists a clear distinction between the recession in 1982/83 and the one starting in 1988. First, the negative shock was more severe in 1988 and 1989 as is seen from Figure 1a with a decline in net employment change in manufacturing from –0.4 percent in 1987 to -6.0 percent and -7.5 percent in 1989, as compared to a decline from -2.9 to -6.5 percent from 1982 to 1983. Second, the recession in the late eighties was more persistent in that the decline in net employment change is below

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8 The measures of job creation and destruction reported in figure 1 are defined in appendix B.

average following the years 1988-89.[9] Hence our data set allows us to test plant exit both during a relatively mild and strong recession.

In Figure 1b we also present the components of job turnover over time. See the Appendix for definitions of job creation and job destruction. It is clear from Figure 1b that job creation and destruction from plant turnover (exit/entry) is quite stable. Further, job creation from incumbents (INCR) is fairly stable and independent of the business cycle as represented by (NET); the standard deviation is 0.008. However, the driving force in explaining the counter-cyclicality of the gross job turnover in Figure 1b, is the job destruction rate by incumbents (DECR). This is confirmed by the standard deviation for DECR is 0.016 indicating a somewhat more volatile destruction rate than job creation rate. The fact that the two (gross) components of the activity in job reallocation in the economy have this asymmetry reflects the negative relationship between total turnover (SUM) and the net activity (*NET*) in Figure 1b.

Focusing now on the role of exits relative to incumbents in restructuring in a mild and strong recession, estimated Pearson correlation coefficients and Spearman rank coefficients are presented in Table 1. Coefficients for the whole data period, for the minor recession in 1982/83 using data for 1977-86, and for the major recession using data from 1987-92. P-statistics are given in the parentheses. Considering the counter-cyclicality of gross turnover for the whole data period first, i.e., the correlation between SUM and NET, both the Pearson's and Spearman's rank coefficients indicate a significant negative relationship with correlations of -0.665 and -0.566, respectively. For comparison the Pearson correlation is -0.54 for the US (1972 to 1986, i.e., including the first oil shock), and -0.25 for Canada (1972 to 1986). Now, looking at the correlation coefficients between SUM and NET for the minor (second line) and major (third line) recessions, the gross turnover is far from being significant for the minor downturn but strongly significant in the major one.[10] Employment reduction is counter-cyclical

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9 Also the unemployment rate for the whole economy was rising during most of the period; increasing from below 2 percent in 1981 to above 3 percent in 1983, dropping to above 2 percent in the boom 1985/86, then rising again in the recession in the late eighties to above 5 percent and to about 6 percent in 1992/93.

10 Boeri (1996) using similar data for Norway for the period 1976-86, also fails to find a significant counter-cyclical pattern for gross job turnover in Norway. Boeri only finds a significant counter-cyclical relationship for the US and not for European countries and for Canada. He points to possible explanations as differences in the size compositions of plants of the samples in the US and Europe, and that the service sector is included in most of the European studies. Our result indicates an alternative explanation in that one should distinguish between the effect of a minor and a major slump. Considering the data periods used in Boeri (1996), we notice that only the data set for US includes a major recession from the first oil shock in the early seventies, while all the other economies analysed had only mild recession and booms.

for incumbent firms both in the minor and major recessions, but in the minor recession it is not strong enough to make the total turnover counter-cyclical. What is more interesting in our context though, is that the exit rate is strongly counter-cyclical in the major downturn but not important in the minor recession. Hence, there appears to be a structural difference in terms of adaptation to a mild and severe recession. The minor downturn appears only to be an adaptation to the negative shock and no counter-cyclical pattern of job turnover is detected. In contrast to a major recession where both the adjustments of continuing plants and of exiting plants are important.

4. Empirical Results

4.1 Testing for a vintage effect

Table 2 presents the estimated parameters for 4 different versions of the probit specification of the exit model. The sign of estimated parameters provides information on whether the probability of exit increases or decreases in the associated variable. A positive sign implies that the probability of exit increases in the associated variable, while a negative sign implies decreasing exit probability.

Columns 1 and 2 present the estimated coefficients and t-values of the model only including second-order polynomials of the age of the plant and age of the capital. The estimation results strongly support the assertion that one should differentiate between the age of the plant and the vintage of its capital equipment. These two effects work in opposite directions with respect to exit probability. The likelihood of plant shutdown is significantly decreasing and convex in plant and the probability of shutdown increases significantly as the age of the machine capital increases.

Before we evaluate the implications of the estimated parameters for the strength of the vintage capital and learning effects on the exit probability over an establishment's life-cycle, the stability of the estimated model will be assessed. In columns 3 and 4 we test whether the exit pattern is stable when observable variables such as the size of the plant and profitability (profits per worker) are introduced. For instance the size of the plant may pick up the effect of the evolution/selection effect since plants are usually small when they are established. The measure used for profitability may be highly correlated with productivity, expected to be the driving force both in theories of selection and for the vintage capital model. The results show that the probability of exit is decreasing and convex in plant size (LNEMPL) as expected. We also see that increasing profitability (PROFEMPL) is associated with lower exit probability in all models. However, the estimated first-order coefficients for plant age and capital age is only slightly reduced and still significant.[11]

Next, we test how stable the results are when in addition to establishment size and profitability, plant specific random effects (columns 5 and 6), and industry-specific (4-digit ISIC level) fixed effects (columns 7 and 8) are introduced. For both these specifications the effect of plant age and capital vintage on shutdown probability remain roughly the same. The industry fixed effect model can be interpreted as providing the within industry exit pattern. Hence, the observed exit probability increasing in the age of capital and decreasing in the age of the establishment is due to the dynamics within industries and not an artefact of differences over industries, for instance, when some industries only have a vintage effect and some only a selection effect.

We turn now to evaluating the pattern of exit probability the estimated model predicts for a firm over the life-cycle for different assumption regarding the capital reinvestments.[12] Three cases are tested and plotted in Figure 2. We use the results from the simplest model since the results from the extended models are not very different. First, the extreme case of no reinvestments or the pure vintage capital model is assumed, where the age of the capital increases one-to-one with the age of the plant. At the other extreme we allow the reinvestment pattern to be such that the machine capital are continuously replaced. One case in between is also presented where some degree of reinvestment is allowed for. Concentrating first on the pure vintage model, we see from the pattern pictured in Figure 2 that the exit probability decreases the first years after entry, and reaches its lowest level when the plant is 13-15 years. Thereafter the exit probability increases. Hence, according to our results it seems as learning effects dominate in the first years of the plant's life, but that these are exhausted when the plant has passed the age of ten. Thereafter, capital vintage effects dominate, leading to an increase in

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11 Whether the plant is owned by a multi-plant operation or a single-plant firm was also tested but not found to have any significant effect on firm survival.

12 We graph the predicted exit probabilities since the probit parameter estimates cannot be interpreted in the same manner as for the standard regression model with continuous variables. The magnitude of the increase in exit probability with a marginal increase in one of the x's depends on the prior value of $\Phi(\beta'\mathbf{x})$, due to its S-shape. If $\Phi(\beta'\mathbf{x})$ already is close to 1, a further increase in $\beta'\mathbf{x}$ will only lead to a very small increase in the exit probability.

the probability of exit. Our results suggest that theories of industry dynamics stressing learning effects are most relevant in the first decade of the establishment's existence, even when it allows the average age of its capital equipment to increase. Thereafter, the vintage capital effect explains plant attrition. The other extreme case, where there is a continuous renewal of the machine capital, shows as expected a more L-shaped exit probability curve and no vintage effect. However, for the intermediate case with some reinvestments, the exit curve over the life cycle of a curve shows a more U-shaped pattern.

An alternative approach to validate the model and assess the implications of the estimated parameters is to evaluate the exit probability in the age of the establishment for different *observed* values of the age of capital, and *vice versa* with the exit pattern in the age of the establishment. In Figure 3a we present a three-dimensional plot of the exit probabilities over age of capital and age of plant, while Figure 3b depicts the density of plants in a three-dimensional plot. According to Figure 3a the likelihood of exit decreases rapidly in the first few years, but stabilises at rather low levels when the plant is around ten years old. Together with the findings from figure 2 this confirms that the effects of learning and selection apparently are exhausted when the plant has been in existence for a decade. However, we also notice that the vintage effect is strong for all levels of the age of the plants. However, old plants with new capital equipment have the smallest exit probabilities. At the other extreme, younger plants with old capital equipment have the highest probability of failure. We also see that the exit probability increases faster in machine capital for younger plants than for older plants. Now turning to the density of exiting plants in Figure 3b, we notice that most of the exit activity is taking place for plants within 20 years of age and age of capital lower than 25 years.

In sum, our results show a strong U-shaped exit probability pattern where both the learning/selection effect and the capital vintage effect are present over the life cycle of an establishment. However, how important the vintage capital effect is may depend on market characteristics such as the degree of sunk costs and price volatility as analysed in Lambson (1991). In the next section the exit rates are analysed in industries with high and low levels of sales of capital equipment to capital stock ratios, which are used as proxies for sunk costs.

4.2 The vintage effect and the degree of sunk costs.

In Table 3 the two simplest specifications of the exit models are presented for industries with high and low ratios of sales of capital equipment to capital stock. The sales figures include only capital equipment previously used as input in the plant's production. A high sales ratio indicates a low degree of sunk costs since and active second-hand market is existing, while a low sales ratio indicates a high degree of sunk costs (Mørch von der Fehr, 1991). Descriptive statistics for the two sub-samples associated with low and high sales of capital equipment to capital stock are presented in Appendix C.

In Lambson's (1991) model the motivation for predicting a weak vintage effect in industries characterised by low sunk costs is that new firms will choose both standard and advanced technologies and thus some variability in exit rates is expected. Industries with high sunk costs, on the other hand, are expected to choose the same technology when they enter. From the results in Table 3 we note that the capital age effect is significantly positive also in the case of high capital sales ratio industries, and even higher than for low capital sales ratio industries. Now, to check which exit pattern the estimated coefficients provides we plot the exit probability in the age of the establishment assuming the pure vintage model with no reinvestment in Figure 4a and 4b. This assumption is also explicitly stated in Lambson (1991). From the Figure 4 we observe a distinct difference in the exit pattern for the case of high and low sunk costs: While a strong vintage effect is present in addition to the learning effects where low sunk costs characterises the market, the vintage effect is much weaker with high sunk costs (low sales ratio). This result contradicts the predictions from Lambson (1991), but it again emphasises different market characteristics in explaining producer heterogeneity.

4.3 Exit probability over the business cycle

Next, we examine the estimated relationships between exit probabilities and business cycle indicators. Results are provided in Table 4. The coefficients of two continuous business cycle indicators (columns 1 to 4), NETRATE and GDPGROW, predict that the probability of shutdown decreases as the growth rate of the Norwegian economy increases. However, the coefficient GDPHP (columns 5 and 6) shows a negative sign, but is not significant, suggesting that decision makers may be less concerned with deviations from trend growth.

Using the dummy variable approach to pick up the two recession periods provided in columns 7 and 8, support the results using continuous indicators. Note that the recession dummy variable is normalised to take the value -1 in a recession. Most interestingly is the results when we differentiate between a small and deep recession (columns 9 and 10); the exit probability increases in the period with the most pronounced recession, 1988-92. However, in the years with a weak recession, the likelihood of exit is not significantly different from the years of expansion in the Norwegian economy. This confirms the descriptive statistics in Table 1 and Figure 1.

Next, we introduce interaction terms between the recession dummies and plant age and capital age to see if older plants or plants with old machine capital equipment are more likely to shut down in recessions. According to the empirical results presented in columns 1 and 2 of Table 5 plants with old machine capital have a significantly higher probability of exit in recessions (cf. *RECAPAGE*). Plant age does not seem to have any significant effect on the likelihood of exit in recessions (cf. *RECPAGE*). Distinguishing between a weak and strong recession presented in columns 3 and 4, we find that establishments with old capital have the highest probability of exit both during a weak and strong recession (cf. *WRCAPAGE* and *SRCAPAGE*). Somewhat surprisingly plant age only have a significant effect on plant shutdown probability in the weak recession (cf. *WRPAGE* and *SRPAGE*), with young plants having the highest probability of exit. Overall our results support the assertion that recessions are periods of cleansing, where plants with old capital equipment are shut down.

5. Concluding remarks.

The aim of the present study has been to examine an alternative vintage capital model to the learning/selection model to explain exit rates. In spite of the large and growing literature on producer heterogeneity and firm exit behavior, little attention has been paid to the capital vintage theory of firm exits as an alternative hypothesis. Interpreted at the firm level this theory predicts that plants with old vintages of capital have higher exit rates than plants with more recent vintages of capital. Our hypothesis is that both effects occur, predicting a U-shaped pattern in exit rates. The failure rate is first expected to decrease in plant age due to selection and/or learning effects, and then to increase due to the capital vintage effect. The main results are as follows. Using a panel of Norwegian manufacturing plants and using an index of capital age in addition to the age of the plant, we are able to disentangle the effects of learning and capital vintage on exit rates. The empirical results suggest a U-shaped exit function in the age of the plant implying that both a learning effect and a vintage capital effect are present. The vintage capital effect is also present under different assumptions concerning the rate of investments in machine capital, when other observable variables than the age of machinery and establishment age are introduced, as well as when unobserved establishment characteristics are included by a random effect model.

In order to test how the strength of the vintage effect might depend on market conditions, we test a prediction from Lambson's (1991) model, where the model predicts a weak vintage effect in industries characterised by low sunk costs in that entering firms will choose both standard and advanced technologies and thus a variability in exit rates is expected, while in industries with high sunk costs producers are expected to choose the same technology. Testing the prediction from Lambson (1991), we find a distinct difference in the exit pattern for the case of high and low sunk costs, but where the results contradict the predictions from Lambson (1991).

At last, the paper contributes to the controversial point of whether restructuring is clustered in downturns via a "shake-out" effect on plants or a "cleansing" effect. The exit rates are found to be counter-cyclical, especially in that exits increase in a severe downturn. Using interaction terms between the business cycle indicators and the age of capital, we find that plants with old vintages of capital have higher exits rates during a downturn. Hence, our results support the assertion that macro economic downturns are periods of cleansing, where old capital equipment is scrapped.

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Appendix

Appendix A. Summary Statistics of Original and Estimating Sample

The most significant reduction in observations, from 52411 to 13495 is experienced when plants with less than five employees in one or more years are dropped. The EXIT rate declines markedly, and the average size of the plants (LNEMPL) is doubled. When plants with missing data on capital and investments are dropped the sample is reduced to 12499 observations, and the changes in the mean values are rather small.

Table A. Summary Statistics of the Sample

Variable	Plants with plant age observed		Plants with >=5 employees all years		Estimating sample	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
EXIT	0.116	0.320	0.068	0.252	0.0747	0.263
CAPAGE	N.A.	N.A.	N.A.	N.A.	5.295	3.470
PLANTAGE	6.453	5.631	7.914	6.268	7.376	6.098
LNEMPL	1.590	1.193	3.034	0.985	2.997	0.948
PROFEMPL	N.A.	N.A.	0.044	0.170	0.042	0.174
No. of obs.	52411		13495		11174	

Appendix B. Definitions of job creation and job destruction

The aggregate job turnover rates for an industry or a sector, are the sum over the employment change rates of new, expanding, declining and dying establishments in industry *i* in year *t*,:

$$ENTRY_{i,t} = \frac{2}{L_{i,t-1} + L_{i,t}} \sum_{\substack{e \notin E_{i,t-1} \\ e \in E_{i,t}}} L_{e,t} \qquad INCR_{i,t} = \frac{2}{L_{i,t-1} + L_{i,t}} \sum_{\substack{e \in E_{i,t-1}, E_{i,t} \\ dL_{e,t} > 0}} (L_{e,t} - L_{e,t-1});$$

$$EXIT_{i,t} = \frac{2}{L_{i,t-1} + L_{i,t}} \sum_{\substack{e \in E_{i,t-1} \\ e \notin E_{i,t}}} L_{e,t-1} \qquad DECR_{i,t} = \frac{2}{L_{i,t-1} + L_{i,t}} \sum_{\substack{e \in E_{i,t-1}, E_{i,t} \\ dL_{e,t} < 0}} \left| L_{e,t} - L_{e,t-1} \right|$$

respectively, where $E_{i,t}$ is the set of establishments in industry *i* in year *t*, and $L_{i,t}$ is the total employment in industry *i*, defined by:

$$L_{i,t} = \sum_{e \in E_{i,t}} L_{e,t} .$$

The *gross job creation* and *gross job destruction* rates of industry *i* in year *t* are given by:

$$POS_{i,t} = INCR_{i,t} + ENTRY_{i,t} \quad \text{and:} \; NEG_{i,t} = DECR_{i,t} + EXIT_{i,t}$$

respectively. The *net employment change* (or *net job reallocation*) rate is given by:

$$NET_{i,t} = POS_{i,t} - NEG_{i,t} ,$$

while the *gross job reallocation* (or *turnover*) rate is defined by:

$$SUM_{i,t} = POS_{i,t} + NEG_{i,t} .$$

Appendix C. Samples by Degree of Sunk Costs

Table B. Summary Statistics for sub samples associated with low and high industry mean ratio of sales of capital equipment to capital stock.

Variable	Low Sales Ratio Sample		High Sales Ratio Sample	
	Mean	Std. Dev.	Mean	Std. Dev.
EXIT	0.071	0.256	0.079	0.269
CAPAGE	5.448	3.487	5.139	3.445
PLANTAGE	7.692	6.173	7.055	6.004
LNEMPL	3.072	0.954	2.921	0.936
PROFEMPL	0.047	0.212	0.037	0.125
NETRATE	-0.023	0.027	-0.024	0.027
GDPGROW	1.451	2.275	1.359	2.291
GDPHP	-0.313	1.415	-0.331	1.417
SALECAP*	0.004	0.001	0.010	0.005
No of obs.	5638		5536	

*SALECAP = industry mean ratio of sales of capital equipment to capital stock.

TABLES

Table 1. Time series properties of gross job flows in Norwegian manufacturing, 1977-92.

Year	Pearson corr. r(NET,SUM)	r(NET,DECR)	r(NET,EXIT)	Spearman rank (NET,SUM)	(NET,DECR)	(NET,EXIT)
1977-92	-0,665	-0,969	-0,701	-0,566	-0,935	-0,580
	(0,005)	(0,000)	(0,003)	(0,022)	(0,000)	(0,018)
1977-86	-0,258	-0,942	-0,289	0,086	-0.085	0.003
	(0.471)	(0,000)	(0,418)	(0,814)	(0,0018)	(0,993)
1987-92	-0,900	-0,986	-0,928	-0,841	-0,943	-0,928
	(0,015)	(0,003)	(0,008)	(0,036)	(0,005)	(0,008)

Note: P-values in the parentheses.

Table 2. Estimated Parameters of Probit Models of Plant Exit.

	Coef.	t-value	Coef.	t-value	Coef.	t-value	Coef.	t-value
Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CAPAGE	0.048	2.370	0.043	1.935	0.040	1.855	0.041	1.844
CAPAGE2	-0.0007	-0.987	-0.001	-1.063	-0.001	-0.953	-0.001	-1.029
PLANTAGE	-0.203	-12.961	-0.159	-9.447	-0.169	-10.253	-0.152	-8.947
PLANTAGE2	0.006	9.804	0.005	6.902	0.005	7.354	0.004	6.301
LNEMPL			-0.873	-7.914	-0.860	-8.115	-0.831	-7.393
LNEMPL2			0.089	5.255	0.089	5.481	0.081	4.660
PROFEMPL			-1.105	-6.936	-1.121	-6.275	-1.131	-6.959
Constant	-0.879	-18.284	0.678	4.053	0.672	4.148	0.495	2.164
Pseudo-R^2	0.087		0.130				0.137	
Log-likel.	-2710.99		-2583.84				-2562.70	

Table 3. Probit Model Estimates for Plant Exit by Ratio Sales of Capital to Capital Stock.

Variable	Low Sales Share Sample				High Sales Share Sample			
	Coef.	t-value	Coef.	t-value	Coef.	t-value	Coef.	t-value
CAPAGE	0.034	1.146	0.030	0.937	0.061	2.131	0.054	1.721
CAPAGE2	0.000	-0.325	0.000	-0.375	-0.001	-1.008	-0.001	-1.043
PLANTAGE	-0.188	-8.293	-0.143	-5.912	-0.218	-9.850	-0.174	-7.320
PLANTAGE2	0.005	5.738	0.004	3.775	0.007	7.951	0.006	5.876
LNEMPL			-0.794	-4.347			-0.905	-6.607
LNEMPL2			0.071	2.436			0.100	4.848
PROFEMPL			-0.919	-4.697			-1.480	-5.306
Constant	-0.876	-12.569	0.626	2.314	-0.882	-13.127	0.685	3.211
Pseudo-R^2	0.0923		0.1414		0.0820		0.1207	
Log-l.	-1308.25		-1237.38		-1401.28		-1342.18	

Table 4. Probit Model Estimates for Plant Exit over the Business cycle.

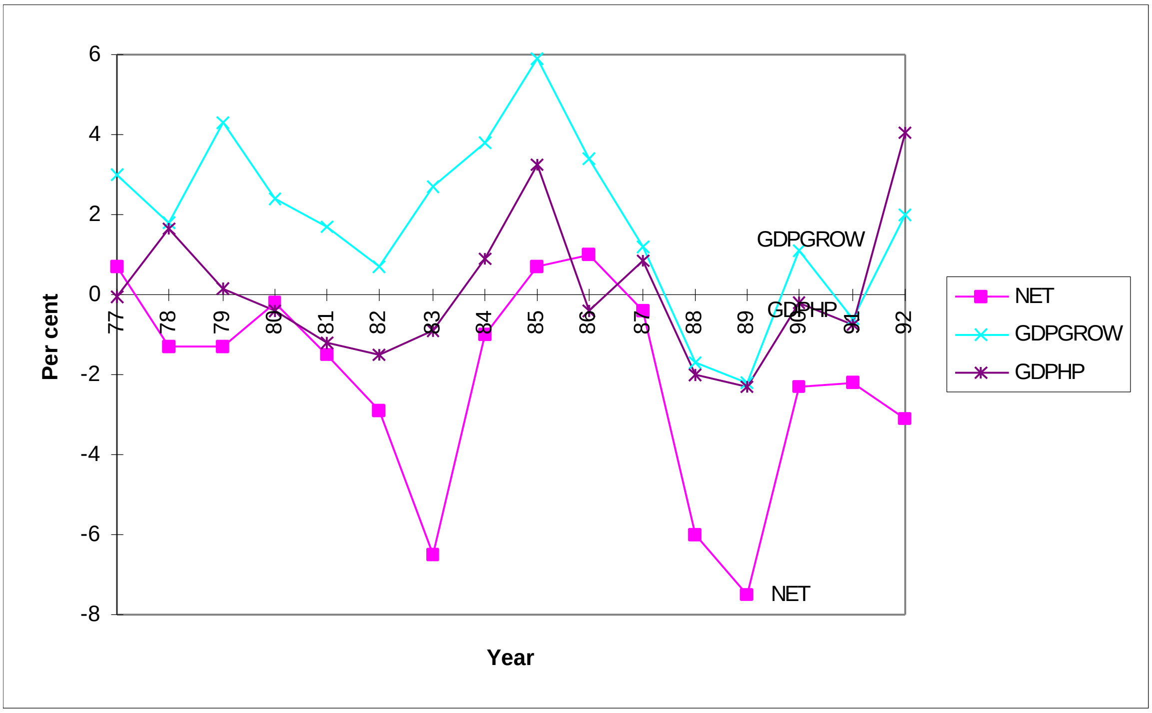
	Coef.	t-value	Coef.	t-value	Coef.	t-value	Coef.	t-value	Coef.	t-value
Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CAPAGE	0.044	7.817	0.040	1.852	0.042	1.904	0.043	1.949	0.037	1.684
CAPAGE2	-0.001	-5.054	-0.001	-0.831	-0.001	-0.971	-0.001	-1.013	-0.001	-0.815
PLANTAGE	-0.161	-14.341	-0.159	-9.394	-0.159	-9.452	-0.160	-9.475	-0.154	-9.090
PLANTAGE2	0.005	11.534	0.005	6.753	0.005	6.879	0.005	6.905	0.004	6.496
LNEMPL	-0.870	-7.883	-0.868	-7.858	-0.872	-7.903	-0.870	-7.883	-0.870	-7.875
LNEMPL2	0.089	5.305	0.089	5.231	0.089	5.249	0.089	5.242	0.090	5.254
PROFEMPL	-1.099	-6.806	-1.090	-6.834	-1.103	-6.920	-1.104	-6.924	-1.101	-6.897
NETRATE	-1.522	-2.279								
GDPGROW			-0.030	-3.551						
GDPHP					-0.015	-1.115				
RECESS							-0.078	-2.007		
WEAKRE									0.070	1.108
STRONGRE									-0.121	-2.952
Constant	0.637	2.378	0.714	4.252	0.672	4.019	0.632	3.743	0.636	3.762
Pseudo-R^2	0.1305		0.1318		0.1299		0.1304		0.1320	
Log-likel.	-2581.53		-2577.51		-2583.21		-2581.82		-2577.13	

Table 5. Probit Model Estimates for Plant Exit over the Business Cycle with Interaction Terms.

	Coef.	t-value	Coef.	t-value
CAPAGE	0.013	0.524	0.003	0.136
CAPAGE2	0.000	-0.492	0.000	-0.119
PLANTAGE	-0.152	-8.715	-0.129	-7.247
PLANTAGE2	0.005	6.533	0.004	4.611
LNEMPL	-0.864	-7.812	-0.871	-7.826
LNEMPL2	0.089	5.214	0.090	5.241
PROFEMPL	-1.099	-6.896	-1.095	-6.847
RECESS	0.040	0.601		
RECAPAGE	-0.050	-2.474		
RECPAGE	0.020	1.533		
WEAKRE			0.022	0.165
STRONGRE			0.032	0.449
WRCAPAGE			-0.140	-2.076
WRPAGE			0.157	2.988
SRCAPAGE			-0.042	-2.048
SRPAGE			0.006	0.450
Constant	0.693	4.033	0.685	3.969
Pseudo-R^2	0.1314		0.1363	
Log-likel.	-2578.7		-2564.3	

FIGURES

(a)



(b)

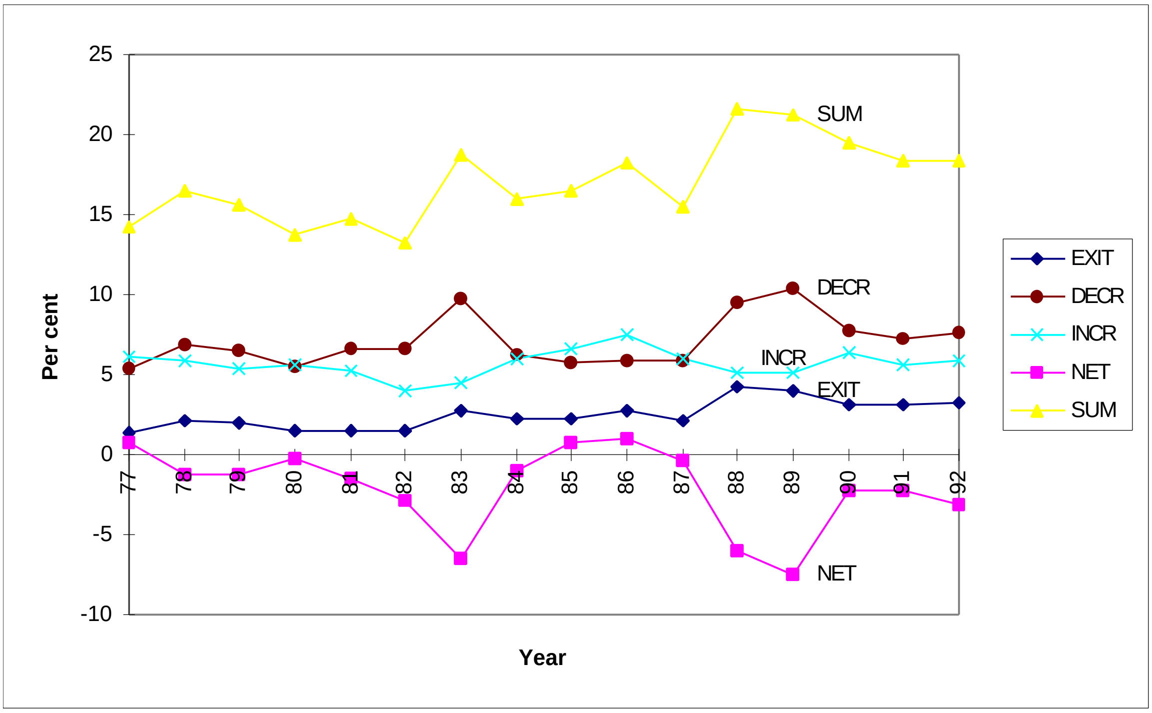


Figure 1. The Time Pattern of the Net Job Reallocation Rate and its components plus other Business Cycle Indicators.

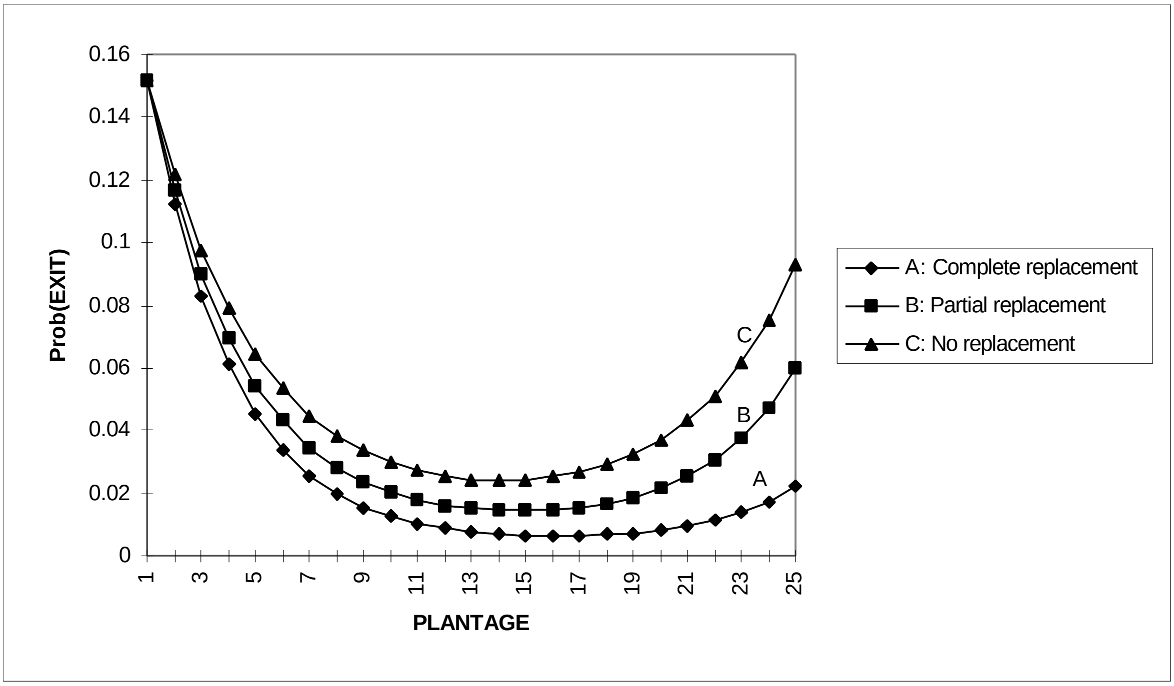
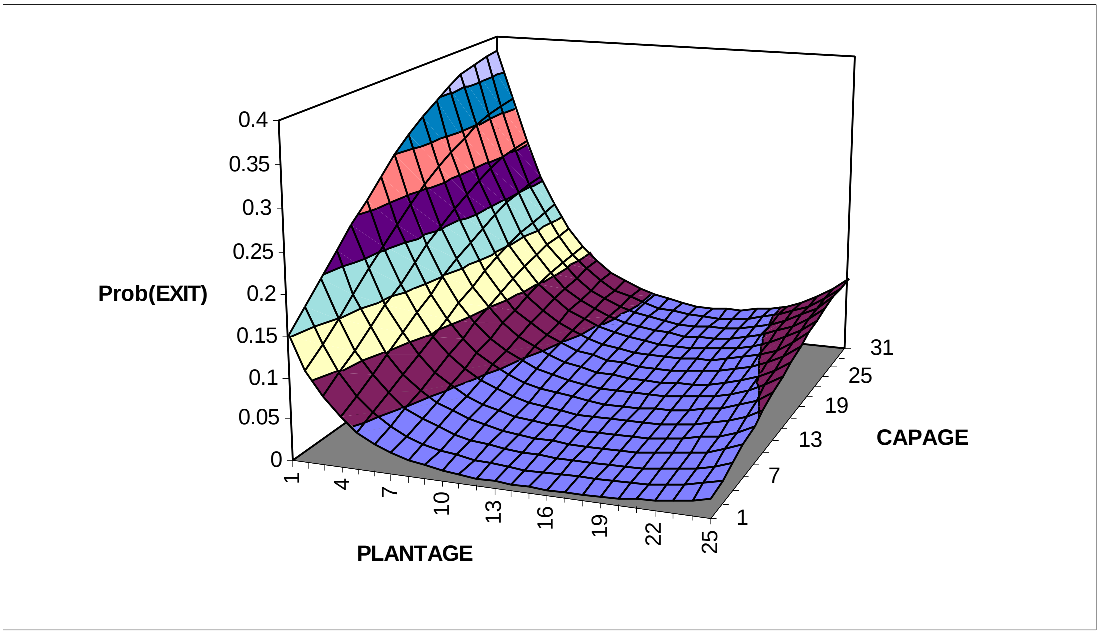


Figure 2. Predicted Exit Probabilities for Different Assumptions on Replacement of Machine Capital: (A) Complete, (B) Partial and (C) No Replacement Each Year

(a)



(b)

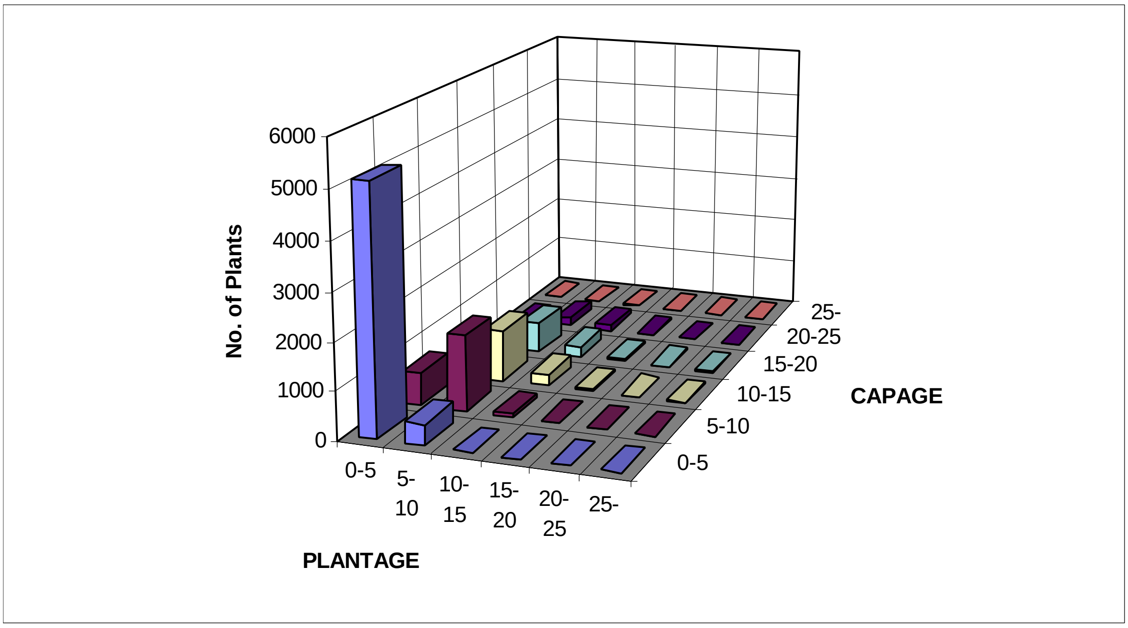


Figure 3. (a) Predicted Exit Probabilities as a Function of Establishment Age (PLANTAGE) and Age of Capital (CAPAGE) and (b) Density of Plants.

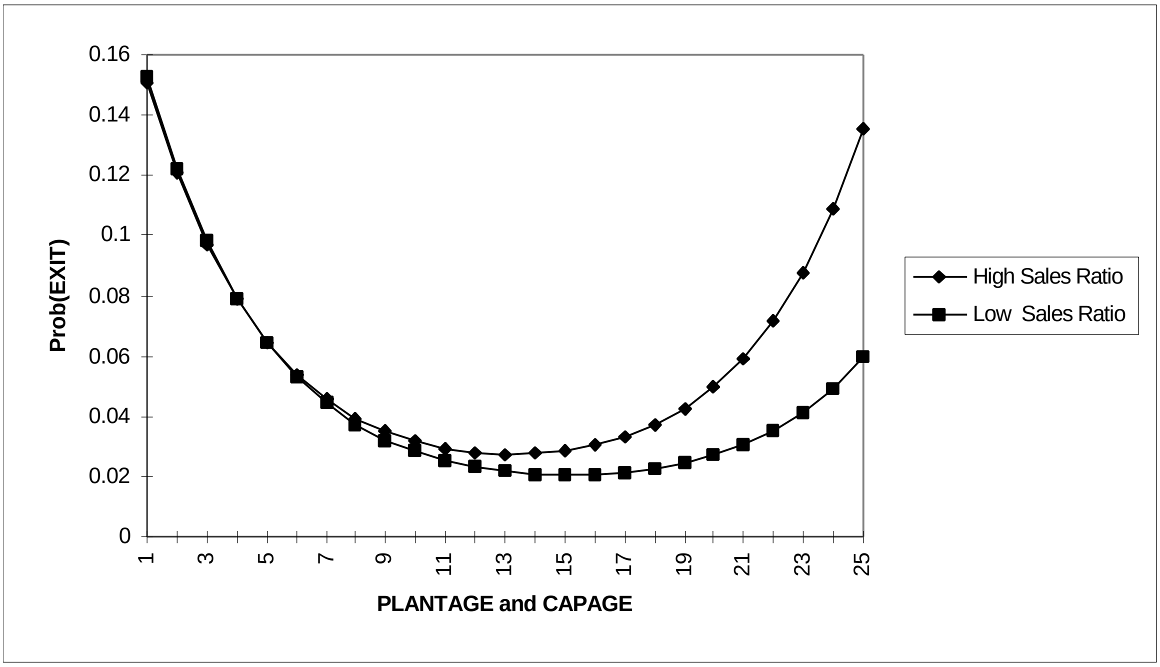


Figure 4. Predicted Exit Probabilities for High and Low Sales Capital-Capital Stock Ratios.