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**FIRM DYNAMICS AND PRODUCTIVITY GROWTH: A REVIEW OF MICRO EVIDENCE FROM
OECD COUNTRIES**

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by
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ABSTRACT/RÉSUMÉ

This paper surveys recent empirical studies exploring aggregate productivity growth based on firm dynamics, focusing on micro-data from OECD countries. Aggregate productivity growth can be analysed as a sum of two separate processes. *i*) Changes in productivity in individual firms at a given size (relative to market). And, *ii*) a reallocation process due to compositional effects arising from the expansion and contraction of existing firms as well as from entry and exit of firms (namely, firm dynamics). After reviewing theoretical explanations and empirical methods for firm dynamics and productivity growth, the paper looks into major findings from the manufacturing sector under three subsections: firm dynamics, productivity correlates, and productivity decomposition. The paper also reviews methodological issues and some findings from the emerging literature of empirical studies on the service sector.

JEL classification: D21, D24, O12, O30, O47.

Keywords: firm, productivity, micro-data, OECD.

Cette étude passe en revue les études empiriques récentes qui examinent la croissance de la productivité globale en se basant sur la dynamique de l'entreprise, et en particulier en utilisant des données individuelles de firmes de pays de l'OCDE. La croissance de la productivité globale peut être analysée comme étant le résultat de deux procédés distincts, soit *i*) les changements de la productivité des firmes individuelles à taille donnée (par rapport au marché); et *ii*) le processus de réallocation dû à l'expansion et à la contraction des firmes existantes, aussi bien qu'à des entrées et sorties des entreprises (à savoir, la dynamique de l'entreprise). Après avoir examiné les explications théoriques et les méthodes empiriques d'analyse de la dynamique de l'entreprise et de la croissance de la productivité, l'étude considère les résultats principaux du secteur manufacturier dans trois sous-sections : la dynamique de l'entreprise, les corrélats de la productivité et la décomposition de la productivité. L'étude analyse également les questions méthodologiques et les conclusions principales émanant des études empiriques sur les secteurs des services.

Classification JEL : D21, D24, O12, O30, O47.

Mots-clés : entreprise, productivité, micro-données, OCDE.

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FIRM DYNAMICS AND PRODUCTIVITY GROWTH: A REVIEW OF MICRO EVIDENCE FROM OECD COUNTRIES

Sanghoon Ahn¹

I. Introduction

1. This paper surveys recent empirical studies exploring determinants of aggregate productivity growth based on micro-data, mainly at the enterprise- or establishment-level.² Such studies have found large and persistent differences in productivity levels across firms even within the same sector. Moreover, a substantial portion of aggregate productivity growth is found to be attributable to resource reallocation across such heterogeneous firms, from shrinking/exiting low productive firms to expanding/entering high productive firms.³ The importance of these firm dynamics in aggregate productivity growth is being recognised in the growing body of empirical research in many countries.⁴ Findings from those empirical studies were reviewed by Geroski (1995), OECD (1998, Ch.4), Caves (1998), Foster *et al.* (1998), Bartelsman and Doms (2000), and Haltiwanger (2000), among others. This paper provides an updated literature survey and extends the scope of the review beyond the manufacturing sector.

2. Aggregate productivity growth can be analysed as a sum of two separate processes:

- i) Changes in productivity in individual firms at a given size (relative to market).
- ii) A reallocation process due to compositional effects arising from the expansion and contraction of existing firms as well as from entry and exit of firms (namely, firm dynamics).

In the rest of the paper, each of the two processes will be analysed and their relative contribution to aggregate productivity growth will be considered.

3. The paper consists of five sections. Section II reviews theoretical explanations and empirical methods for firm dynamics and productivity growth. Section III looks into major findings from empirical

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2. Throughout this paper, "enterprise" and "firm" are used interchangeably referring to a legal unit of business, while "establishment" and "plant" are used for a physical unit of production. A firm could be either a single-plant firm or a multi-plant firm. For examples of this terminology, see Audretsch and Mahmood (1995) and Caves (1998), among others.

3. For example, the contribution from such firm dynamics (in which less efficient business units exit and more efficient ones enter and increase market share) accounted for around 50% of labour productivity growth and 90% of total factor productivity growth in the UK manufacturing over 1980-92 (Disney *et al.*, 2000).

4. However, international comparisons of firm dynamics and productivity are difficult and rare. See OECD (2001, Ch.7) for emerging evidence from an ongoing project based on firm-level data from ten OECD countries.

studies under three subsections: firm dynamics, productivity correlates, and productivity decomposition. Section III.1 explores the pattern and determinants of birth and death, growth and decline of individual firms. Section III.2 reviews findings from empirical studies examining various influences on productivity growth in individual firms: technology, human capital, ownership structure, competition, and international trade. Section III.3 separates and compares the contribution of compositional shifts to aggregate productivity growth from that of within-plant productivity growth. The majority of studies on firm dynamics and productivity growth have so far focused on the manufacturing sector. In fact, however, the service sector accounts for even larger and still growing share of the economy in most OECD countries. Section IV reviews methodological issues and some findings from the emerging literature of empirical studies on the service sector. Section V summarises the paper.

II. Theoretical Explanations and Empirical Methods

II.1 Theoretical explanations

II.1.1 Innovation and creative destruction

4. Economic growth models based on the usual assumption of a representative producer/consumer cannot take into account the widely observed heterogeneity of producers (in size, age, technologies, productivity levels, etc.) even in a narrowly defined sector. Thus, such models cannot adequately explain the observed high rates of birth and death of firms, nor their observed patterns of survival and adjustment. A theoretical framework for links between firm dynamics and economic growth can be found in Schumpeterian “*creative destruction*” models.⁵

5. In the Schumpeterian model, a new innovator enters a market with new technology and competes with incumbents with conventional technology. If the innovation is successful, the entrants will be able to replace the incumbents. If not, they will fail to survive. Competition weeds out the unsuccessful firms and nurtures the successful ones. When incumbents which have already accumulated substantial experience with conventional technology are less enthusiastic about taking risks of adopting new technology,⁶ new entrants aggressively experimenting with new technology can be a driving force of innovations. Aggregate productivity evolves with successive innovations through entry and exit, while this process reallocates resources from losers to winners. To summarise, “technological advance destroys the economic viability of certain industries, firms, and jobs, as it creates new ones”, and such “reallocation of resources ought to be seen as a key process in productivity growth which governs the pace at which potentialities opened by new technology can be exploited.” (Nelson, 1981)

II.1.2 Experimentation under competition and uncertainty

6. Experimentation under uncertainty helps create micro-level heterogeneity and firm dynamics (Foster *et al.*, 1998). Uncertainty about the demand for new products or the cost-effectiveness of alternative technologies encourages different firms to try different technologies, goods and production

5. See Schumpeter (1934), Nelson (1981), Aghion and Howitt (1992) and Cabellero and Hammour (1994, 1996), amongst others.

6. However, some studies based on micro data show that incumbents sometimes could be as active as new entrants in adopting new technology (Dunne, 1994). One plausible explanation is that incumbents are forced to innovate themselves by the competitive pressure coming from the existence of actual and potential entrants. See below for more discussions on the relationship between use of advanced technology and firm characteristics.

facilities. This generates differences in outcomes and allows firms to learn about their environment and capabilities. The learning process can be “passive” or “active”.

7. In the *passive learning model* (Jovanovic, 1982), a new firm enters a market without knowing its given “type” (potential profitability) *ex ante*. After entry, the firm learns about its own profitability potential based on noisy information from realised profits. By continually updating such learning,⁷ the firm decides to expand, contract, or to exit. The model thus explains why most entrants end up exiting soon after entering the market and predicts that smaller and younger firms will have higher and more variable growth rates.

8. In the *active learning model* (Ericson and Pakes, 1995), a firm explores its economic environment actively and invests to enhance its capability to earn profits under competitive pressure from both within and outside the industry. Its potential and actual profitability changes over time in response to the stochastic outcomes of the firm’s own investment, and those of other actors in the same market. The firm grows if successful, shrinks or exits if unsuccessful. Finding that capital-intensive plants and plants using advanced technology have higher growth rates and lower failure rates, Doms *et al.* (1995) interpreted such findings as consistent with this active learning model, where capital intensity may act as a proxy for unobserved sources of efficiency. In a follow-up study, Pakes and Ericson (1998) tried to compare these two learning models to see which of them is more appropriate for alternative data sets. Based on the evolution of size distribution of the surviving firms from the year 1979 cohort of Wisconsin firms in manufacturing and retailing over eight years, they concluded that manufacturing firms were consistent with the active learning model while retailing firms were consistent with the passive learning model.

II.1.3 Technology and product cycle

9. Firm dynamics are influenced by the technological environment, for example, in the *product life cycle model*.⁸ When a successful new product appears, the market grows rapidly and a large number of new firms enter. As the market matures, the growth of demand decelerates and economies of scale become more important. As a result, the number of firms in such new industries grows at first, then declines sharply, and finally levels off. In the earlier, unsettled stage of the product life cycle, it is relatively easy to enter. But it is particularly difficult to survive through the next stage where the number of firms declines sharply. In the interpretation of Gort and Klepper (1982) by Mata *et al.* (1995), therefore, high rates of turnover (*i.e.* entry and exit) are observed in the earlier stages of product life cycle.

II.2 Empirical methods

II.2.1 Descriptive statistics

10. Firm demographics are summarised by statistics such as entry rate, survival rate, hazard rate, growth rate, etc.⁹ The most easily obtainable statistics are entry, exit, and turnover rates.

- The *entry rate* (or start-up rate) is typically calculated as the number of entrants during a certain period divided by the total number of firms in the sector. Occasionally, gross sales or employment are used as measures of the share of entrants. The gross sales measure is referred

7. It is so-called Bayesian learning in probability theory.

8. See Gort and Klepper (1982), Klepper and Graddy (1990), Klepper (1996), and Agarwal and Gort (1996), among others.

9. See Annex for further discussion on micro databases for studying firm dynamics and productivity growth.

to as the *entry penetration rate* and the employment measure is referred to as *employment-weighted entry rate*.¹⁰

- The *exit rate* is typically calculated as the number of exiting firms during a certain period divided by the total number of firms in the sector. The analogous *employment-weighted exit rate* is calculated by dividing the employment of exiting firms by total (sectoral) employment.
- The *turnover rate* is the sum of entry rate and exit rate in a given sector over a given period.¹¹

11. By tracing a cohort(s) of firms that entered at the same period, one can calculate the survival rate or the hazard rate.

- The *survival rate* is the share of surviving firms in a given year as a percentage of the total number of entrants in the beginning year (*i.e.* share of survivors in a cohort).¹²
- The *hazard rate* is the share of exiting firms in a given year as a percentage of the total number of survivors as of the previous year (*i.e.* it represents continuing firm's conditional probability of failure).¹³
- The *growth rate* of a continuing firm is based on a certain size variable such as employment, sales, net assets etc.

II.2.2 Regression analyses

12. To analyse the patterns of exit/survival and of firm growth, several types of regression analyses have been used in the literature. Explanatory variables have included firm size, firm age, productivity, technology/innovation variables, capital intensity, and ownership structure variables.¹⁴ Survival analysis specifications have included both probability-based survival/exit equations,¹⁵ and more advanced duration-analysis techniques, estimating the relationship between explanatory variables and the continuing firm's conditional probability of exit (*i.e.* hazard rate).¹⁶

13. In *exit regressions*, coefficients for explanatory variables affecting the probability of exit as a discrete dependent variable ($Exit_i = 1$ if the firm i exits in a given year, $Exit_i = 0$ if not) are estimated by Maximum Likelihood (ML) estimation (typically, using a logit or probit functional form):

-
10. As the average size of entrants is much smaller than that of incumbents, entry penetration rates or employment-weighted entry rates are usually much lower than entry rates.
 11. Entry, exit, and turnover rates thus depend upon the time interval in consideration.
 12. By definition, the survival rate is a monotonically decreasing function of time, as fewer and fewer firms survive as time goes by.
 13. Unlike the survival rate, the hazard rate does not have to be monotonically decreasing over time. The empirical hazard rate is often reported to be a \cap -shaped function of time. See below.
 14. For an overview of the results from selected studies, see below as well as Table 1.1 and Table 1.2
 15. Audretsch (1995), Doms *et al.* (1995), Wagner (1994), Boeri and Bellman (1995), Audretsch *et al.*, (1999), Dunne and Hughes (1994), Salvanes and Tveteras (1998), etc.
 16. Audretsch and Mahmood (1994), Honjo (2000), Mata and Portugal (1994), Mata *et al.* (1995), among others.

$\Pr(\text{Exit}_i = 1) = \Pr(X_i\beta + \varepsilon_i \geq 0)$ where X_i is a vector of firm characteristics.

Survival regressions have the same structure.

14. Firm surveys are carried out at discrete points in time (usually once per year), and thus cannot give precise information on when firms enter or exit their markets. Given these data constraints, *duration models* explain the length of survival time (*i.e.* duration) using a set of explanatory variables. The proportional hazard function is a specific case of duration models, where the instantaneous hazard rate function¹⁷ is assumed to be as follows (*hazard regression*):

$$h(t; X_i, \beta) = h_0(t) \exp(X_i\beta)$$

where $h_0(t)$ is the baseline hazard function which does not depend upon firm characteristics, X is a vector of explanatory variables, and β is a vector of coefficients.¹⁸

15. In *growth regressions*, continuing firms' growth rates are explained by various firm characteristics, but are susceptible to selection bias, because low growth firms could have already disappeared from the sample in earlier periods. Such potential selection bias was explicitly considered in some growth regressions (Evans, 1987; Hall, 1987; Doms *et al.* 1995).

II.2.3 Productivity decomposition methods

16. Aggregate productivity in a given sector can be represented by a weighted average of each individual firm's productivity in the sector. That is,

$$P_t = \sum_i \theta_{it} p_{it}$$

where P_t is an aggregate productivity measure (either labour productivity or total factor productivity) for the sector at time t ; θ_{it} is the share of firm i in the given sector at time t ; and p_{it} is a productivity measure of an individual firm i (based on output, employment, man-hour etc.) at time t . Usually, employment (or the man-hour) share is used in weighting labour productivity, and the output share is used for weighting TFP.

17. Aggregate productivity changes can be decomposed into several factors including: *i*) within-firm productivity changes in continuing firms; *ii*) productivity changes resulting from changes in market shares of high-productivity firms and low-productivity firms; and *iii*) productivity changes resulting from the process of entry and exit.¹⁹ Baily *et al.* (1992) used the following decomposition.

17. Instantaneous hazard rate is the continuous time version of the discrete time hazard rate as defined above (conditional probability of failure of a surviving firm during the current period). In a mathematical expression, the instantaneous hazard rate function is defined as $h(t) = \lim_{\Delta t \rightarrow 0^+} \frac{\Pr(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t}$, where T is the firm's life duration.

18. If the coefficient for an explanatory variable in this hazard regression is estimated to be significantly positive, it means that this variable tends to increase the hazard rate of a firm.

19. In productivity decomposition analyses, continuing, entering, and exiting firms are classified in the following way.

- Continuers: observed both in the first year ($t-k$) and the last year (t) of the period.
- Entrants: observed in the last year (t), but not in the first year ($t-k$).

$$\Delta \ln TFP_t = \sum_{i \in C} \theta_{it-k} \Delta \ln TFP_{it} + \sum_{i \in C} \ln TFP_{it} \Delta \theta_{it} \\ + \sum_{i \in N} \theta_{it} \ln TFP_{it} - \sum_{i \in X} \theta_{it-k} \ln TFP_{it-k}$$

where θ_{it} is the output share of firm i in the given sector at time t ; productivity growth ($\Delta \ln TFP_t$) is measured between the base year $t-k$ and the end year t ; and C , N , and X are sets of continuing, entering, and exiting firms, respectively.

18. A problem with the above decomposition method was pointed out by Haltiwanger (1997). If the market share of the entrants is very low and if the market share of the exiters is very high, the net entry effect (sum of the third and the fourth terms in the above expression) could be negative even when entrants are more productive than exiters. To overcome this problem, a modified version of decomposition was offered by Haltiwanger (1997) as follows:²⁰

$$\Delta P_t = \sum_{i \in C} \theta_{it-k} \Delta p_{it} + \sum_{i \in C} \Delta \theta_{it} (p_{it-k} - P_{t-k}) + \sum_{i \in C} \Delta \theta_{it} \Delta p_{it} \\ + \sum_{i \in N} \theta_{it} (p_{it} - P_{t-k}) - \sum_{i \in X} \theta_{it-k} (p_{it-k} - P_{t-k})$$

where Δ refers to changes over the k -year interval between the first year ($t-k$) and the last year (t); θ_{it} is the share of firm i in the given sector at time t ; C , N , and X are sets of continuing, entering, and exiting firms, respectively; and P_{t-k} is the aggregate (*i.e.* weighted average) productivity level of the sector as of the first year ($t-k$).²¹ Under this decomposition method, it is clear that an entrant [exiter] will contribute positively to productivity growth only when it has higher [lower] productivity than the initial industry average.

19. The five components of the above decomposition are defined as follows:

- i) The *within-firm effect* is within-firm productivity growth weighted by initial output shares.
- ii) The *between-firm effect* captures the gains in aggregate productivity, which comes from the expanding market of high productivity firms, or from low-productivity firms' shrinking shares comparing the *initial* firm productivity level with the aggregate productivity level.
- iii) The '*cross effect*' reflects gains in productivity from high-productivity *growth* firms' expanding shares or from low-productivity *growth* firms' shrinking shares.

- Exits: observed in the first year ($t-k$), but not in the last year (t).

Under the above definitions, all firms that entered before the last year of the given period are regarded as entrants and all firms that exited after the first year are regarded as exiters. Therefore, the share of entrants or exiters is likely to increase as the length of the interval (k) increases.

20. There exist several alternative decomposition methods in this vein, including those used by Griliches and Regev (1995), Olley and Pakes (1996), and Baldwin (1995, Ch.9). See Foster *et al.* (1998) for further discussions on alternative decomposition methods. They compare some of those alternative methods and conclude that the quantitative contribution of reallocation to the aggregate change in productivity is sensitive to the decomposition methodology that is employed.

21. The shares are usually based on employment in decompositions of labour productivity and on output in decompositions of total factor productivity.

- iv) The *entry effect* is the sum of the differences between each entering firm's productivity and *initial* aggregate productivity, weighted by its market share.
- v) The *exit effect* is the sum of the differences between each exiting firm's productivity and *initial* aggregate productivity, weighted by its market share.

20. Along with Haltiwanger's decomposition method (hereafter, *Method A*), Foster, Haltiwanger, and Krizan (1998) suggested another closely related version of decomposition (hereafter *Method B*), which is a modification of the decomposition method used by Griliches and Regev (1995):

$$\Delta P_t = \sum_{i \in C} \bar{\theta}_i \Delta p_{it} + \sum_{i \in C} \Delta \theta_{it} (\bar{p}_i - \bar{P}) + \sum_{i \in N} \theta_{it} (p_{it} - \bar{P}) - \sum_{i \in X} \theta_{it-k} (p_{it-k} - \bar{P})$$

where a bar over a variable indicates the average of the variable over the base and end year. While the previous method (*Method A*) uses the first year's values for a continuing firm's share (θ_{it-k}), its productivity level (p_{it-k}) and the sector-wide average productivity level (P_{t-k}), this method (*Method B*) uses the time averages of the first and last years for them ($\bar{\theta}_i$, \bar{P}_i , and \bar{P}). As a result of this time averaging, the third term in the previous method (cross-effect or "covariance" term) disappears in this method.

21. A comparison of the two decomposition methods shows that *Method A* provides a sharper distinction of the within effect, the between effect, and the cross effect. Its within effect reflects the pure contribution of continuing individual firms' productivity growth when there are no changes in their initial shares. Its between effect reflects the pure contribution of share changes under the given initial productivity level. Third, the remaining part of the continuing firms' contribution is captured by the cross-effect term, which reveals whether firms with increasing productivity also tend to increase market share or not. In *Method B*, however, ideas of within and between effects are somewhat blurred in the sense that time averaging means that the within effect term is affected by changes in the shares over time and the between effect term is affected by changes in productivity over time. Moreover, *Method B* does not provide potentially useful information from the cross-effect term. Instead, the first and the second term *Method B* will reflect in part the cross effects in *Method A*, but by an indeterminate amount.

22. Nonetheless, as pointed out by Foster, Haltiwanger, and Krizan (1998), *Method B* has an advantage over *Method A* in that it is less sensitive to random measurement errors. For example, firms with overestimated labour input in a given year will have spuriously low measured labour productivity and spuriously high measured employment share in that year, potentially producing negative covariance between productivity changes and share changes. In this case, the within effect in *Method A* would be spuriously high. Similarly, in case of total factor productivity decomposition using output shares, random measurement errors in output could yield a positive covariance between productivity changes and share changes, and hence, the within effect could be spuriously low. As averaging over time reduces the impact of random measurement errors in a specific year, *Method B* is less vulnerable to such measurement errors.

III. Findings from the Manufacturing Sector

III.1 Firm dynamics

III.1.1 Entry, survival, and growth

23. Descriptive statistics of firm dynamics in different OECD countries in different periods consistently show that many firms enter and exit from all sectors every year. The annual entry rates in the United Kingdom, for example, ranged from 2.5% to 14.5% in 87 three-digit manufacturing industries over the period 1974-79. Entry penetration rates were significantly lower, ranging from 1.5% to 6.4%, because of the relatively small size of entrants (Geroski, 1995). In the United States, averages of five-year entry rates for 387 four-digit SIC industries in the manufacturing sector were between 41.4% and 51.8% over the census periods between 1963 and 1982, and averages of five-year entry penetration rates were between 13.9% and 18.8% (Dunne *et al.*, 1988).

24. High infant mortality of entrants is another common feature of firm dynamics. In the United States, some 60% of entrants exited within five years and 80% exited within ten years. In Portugal, more than 20% of new plants exited during their first year and only 30% of the initial population survived for seven years. In Canada, only 40% of the cohort of entrants in 1971 were still alive in 1982. On the other hand, survivors show substantial growth. On average, surviving new plants doubled their initial size after six years in Germany and in the United States, and after seven years in Portugal. Again on average, plants started by newly created firms were smaller than those created by established firms but grew faster subsequent to entry if they survived (Geroski, 1995; Mata *et al.*, 1995).²²

22. Average growth rates could be overestimated if the average firm size of a cohort increases simply because small firms have exited and disappeared from the cohorts. Some studies (*e.g.* Evans, 1987; Hall, 1987; Doms *et al.*, 1995; Dunne and Hughes, 1994) explicitly considered this selection bias which comes from having only surviving plants (*i.e.* successful plants) in the sample, but the pattern of faster growth in small and young survivors still remained.

III.1.2 Influences on survival and growth

III.1.2.1 Firm size and firm age

25. Regression-based analyses of survival and growth of firms have considered various factors such as firm size, firm age, capital intensity, innovation, productivity, corporate governance structure, etc.²³ Firm size and firm age are consistently important in explaining survival and growth of entrants. For *firm size*, smaller firms tend to have lower likelihood of survival but higher rates of post-entry growth. For *firm age*, older firms showed lower failure rates and lower growth rates in most regression analyses. In particular, survival analyses based on the hazard regressions suggest either negative duration dependence or a \cap -shaped hazard function. Hence, small new firms have both a low probability of survival in the early stages, and a high probability of fast growth if they do survive.

26. These findings are largely consistent with the predictions in the models of experimentation and passive/active learning discussed earlier. A heterogeneous group of entrants learn about their ability to survive and explore and adjust to the competitive environment. Each entrant starts business with different initial size reflecting differences in their own perceived ability and expectation. Those with inadequate competitiveness are forced to exit, while successful survivors grow and try to adjust themselves to the changing environment. The accumulation of experience and assets, in turn, strengthens survivors and lowers the likelihood of failure.

III.1.2.2 Technological/competitive environment

27. Another important implication of the passive/active learning models is that the technological environment and the degree of market competition influence firm dynamics. The product life cycle model also points out that the pattern of firm dynamics evolves along the product life cycle reflecting evolving stages in the market growth, scale economies, and the degree of competition.

28. Major factors affecting firm dynamics include:

- *Innovative environment*: Regression analyses by Audretsch and Mahmood (1994) imply that entrants are exposed to higher risks of failure in industries where small firms tend to have the innovative advantage. This is consistent with the prediction of the product life cycle model. Industries at the early stage of the product life cycle tend to show more turbulent firm dynamics with higher turnover rates.
- *Economies of scale*: In industries with large economies of scale, successful entrants would have to grow fast to reach the minimum efficient scale (MES). Regression analyses in several

23. Empirical studies on this issue include: Dunne *et al.* (1989a and 1989b, US); Audretsch and Mahmood (1994 and 1995, US); Audretsch (1995b, US); Doms *et al.* (1995, US); Honjo (2000, Japan); Wagner (1994, Germany); Boeri and Bellman (1995, Germany); Dunne and Hughes (1994, UK); Audretsch *et al.* (1999, Italy); Mata and Portugal (1994, Portugal); Mata *et al.* (1995, Portugal); and Salvanes and Tveteras (1998: Norway). See Table 1.1 and Table 1.2 for an overview of selected studies.

studies indeed report that an industry-wide measure of MES had positive correlation both with the probability of exit and with survivors' growth.²⁴

- *Competitive environment*: The observation that turnover rates are higher under more innovative environments seems consistent with more general findings that industries with higher entry rates also tend to have higher hazard rates.²⁵ Firms in industries with higher capital intensity or higher innovative efforts (measured by R&D intensity, use of new technologies, etc.) do show higher failure rates on average,²⁶ while an individual firm's capital intensity or innovative efforts appeared to positively related with the firm's survival or growth.²⁷ It is also reported that hazard rates are lower in growing industries while macroeconomic downturns raise hazard rates.²⁸

III.2 Productivity correlates

29. Very rich information can be obtained from micro databases, which link census data with various survey data (R&D, advanced technology use, employees' characteristics, training, ownership structure, etc.). Such databases have been used by researchers to better understand the relationship between firm-level productivity growth and various potential productivity correlates, such as technology, human capital, ownership structure, and competition. Although the number of observations from micro data is usually much larger than the numbers of observation in cross-country or cross-sector regressions, micro analyses could still suffer from measurement problems, model uncertainty, endogeneity/simultaneity of explanatory variables, and omitted variable problems.²⁹ Therefore, findings from focusing on some selected explanatory variables should be weighed against those from focusing on some other factors. Indeed, many studies suggest the existence of complementarity between different productivity correlates (*e.g.* between technology and skills).

III.2.1 Technology and R&D

30. Neo-classical growth models typically assume technological progress to be exogenous. Endogenous growth models have instead emphasised the importance of research and development (R&D) in the production of new technology to explain technological progress within the model. The central role of R&D in the production of new technology ("knowledge capital") is exemplified in Romer (1990). Here it is stressed that technology is a semi-public good characterised by non-rivalry and partial excludability in its use. As such, technology can be accumulated without bound on a *per capita* basis, while at the same time it can be differentiated from a typical public good in that a legal system of patent law or copyright could make it at least partially excludable from its use by free-riders.

24. See Audretsch and Mahmood (1994) and Audretsch (1995b), for example. Parenthetically, Audretsch and Mahmood (1994) also found that initial size and minimum efficient scale (MES) do not seem to explain much about hazard rate in high-tech industries unlike in total industries or in low-tech industries.

25. For example, Mata and Portugal (1994), Mata *et al.* (1995), and Honjo (2000).

26. Audretsch (1995b); Audretsch and Mahmood (1994, 1995), among others.

27. Doms *et al.* (1995); Boeri and Bellman (1995), among others.

28. See Audretsch and Mahmood (1994, 1995); Audretsch (1995b); Mata and Portugal (1994); Mata *et al.* (1995); and Salvanes and Tveteras (1998). On the other hand, a study on two entry cohorts (in 1979 and 1982) of German plants by Boeri and Bellman (1995) found that neither congestion at entry nor cyclical conditions were significant in explaining survival or growth of the plants.

29. For further discussions on this issue in the context of interpreting cross-country growth regression results, see Temple (1999) and Ahn and Hemmings (2000), amongst others.

31. Researchers have focused on R&D as a relatively clearly defined set of activities contributing to changes in techniques and products.³⁰ In addition, many empirical researches on firm level dynamics and productivity growth have included innovation- or technology-related variables as explanatory variables. Their findings show that R&D activities or use of advanced technology are positively correlated with firm performance. Of course, those findings do not mean that any firm can improve its performance simply by increasing its expenditures on R&D or by adopting more advanced technology (See below for more discussions on causality as well as on complementarity between technology and human capital).

III.2.1.1 R&D

32. Most empirical studies estimating the output elasticity of R&D capital or the rate of return to R&D investment, especially those based on aggregate and sectoral data, have reported a strong positive correlation between productivity growth and R&D investment. However, reported correlations from earlier studies using firm-level data were much less strong, especially in the “within-firm” estimates.³¹

33. More recently, Lichtenberg and Siegel (1991) attempted to re-examine the association between R&D and productivity growth, linking the Longitudinal Research Database (LRD) to the National Science Foundation (NSF) R&D survey on over 2,000 companies of the United States. The Longitudinal Research Database (LRD) LRD, which brings together data from the Annual Survey and Census of Manufactures, was used to measure productivity at the firm-level by aggregating plant-level data. The NSF R&D survey allowed the discrimination between the returns to R&D by source of funds (company-financed *vs.* federally-financed) and by character of use (basic research *vs.* applied R&D). The results confirmed the following three findings of existing studies: *i*) positive return to R&D investment; *ii*) higher returns to company-financed research; and *iii*) a productivity “premium” on basic research expenditure.

34. Similar studies have been made for other OECD countries. Hall and Mairesse (1995) used French data constructed by linking the Annual Survey on Enterprise R&D to the Annual Survey of Enterprises. From the data covering 351 manufacturing firms in France (and with a balanced panel of 197 firms over the period 1980-87), they found that the coefficient of R&D capital in the production function remained positive across different model specifications and different estimation methods. However, their results also imply that the R&D coefficients would be substantially lower in the time-series dimension than in the cross-section dimension. According to a study by Odagiri and Iwata (1986) using company financial reports of 311 manufacturing firms in Japan listed on Tokyo Stock Exchange from 1966 through 1983, the rate of return on R&D was estimated to be 20% in the period of 1966-1973 and 17% in 1974-1982. As often found in similar studies, however, the estimated rate of return decreased when industry dummies or the sales growth rate were added to the set of explanatory variables. More recently, based on accounting data for 226 manufacturing companies in Denmark in 1993 and 1995, Dilling-Hansen *et al.* (1999) estimated the output elasticity of the R&D capital stock to be positive (ranging from 12% to 15%).

30. Most econometric studies on the contribution of R&D to productivity growth rely on the Cobb-Douglas production function which includes the stock of technical knowledge (namely, “knowledge capital” or “R&D capital”) as an input in addition to the standard production factors such as labour, physical capital, etc. By running a regression for this augmented production function, one can obtain output elasticity of R&D capital stock. As a close alternative, one can obtain the rate of return to R&D from the regression coefficient of R&D intensity (R&D expenditure relative to output) as an explanatory variable for the total factor productivity (TFP) growth rate.

31. Lichtenberg and Siegel (1991) and Mairesse and Sassenou (1991), among others, provide a good survey of firm-level estimates in the earlier period. To quote a conclusion of Mairesse and Sassenou (1991), “[t]he range of estimates is especially wide; but one cannot be sure whether the difference between them are real and a result, for example, of differences in the period, industry or country considered, or simply a reflection of the peculiarities of the individual studies.”

Parenthetically, they found that foreign-owned firms tended to get greater return to R&D capital than domestic firms.

35. In evaluating the economic returns to innovative activities, the most common way is to relate productivity or profit growth to measures of innovation. As emphasised by Hall (2000), however, long and uncertain lags between spending on innovation and the impact of the innovation make this approach suspect. Instead, some researchers have turned to another way of evaluating the private returns to innovative activity, relating the valuation placed by the financial markets on a firm's assets to its R&D expenditure, patenting activities, and other measures of innovation.³² For example, Hall (1993) found that the stock market's valuation of the intangible capital created by R&D investment in the manufacturing sector had fallen precipitously during the 1980s in the United States. Mairesse and Hall (1996) also report that the R&D contribution to sales or productivity growth was lower in the 1980s than it was in the 1970s in the United States but also in France. In a follow-up study, Hall (2000) finds that the stock market valuation of R&D assets has begun to recover in the mid-1990s, although not to the level of the boom years of the early 1980s.

III.2.1.2 Use of advanced technology

36. In reality, it is not innovation input (R&D investment) *per se* but actual use of innovation output (*i.e.* use of advanced technology) that affects productivity directly. For example, Geroski (1991) demonstrated that innovations had a far greater impact on innovation users' productivity growth than on innovation producers' productivity, based on a database containing 721 UK manufacturing firms over the period 1972-83.³³

37. Some studies have tried to explore relations between technology use and firm characteristics. A pioneering study based on the 1988 Survey of Manufacturing Technology (SMT) in the United States (Dunne, 1994) showed that both old and young plants appear to use advanced manufacturing technology at similar frequencies while larger plants are more likely to employ newer technologies than are smaller plants. A comparable study based on the 1989 Survey of Manufacturing Technology in Canada (Baldwin and Diverty, 1995) also found that plant size and plant growth were closely related to technology use.³⁴

38. McGuckin *et al.* (1998) examined the relation between technology use and productivity by linking the 1988 and 1993 Surveys of Manufacturing Technology (SMT) in the United States with the Longitudinal Research Database (LRD). They found that plants using advanced technologies showed higher productivity, even after controlling for plant size, plant age, capital intensity, labour skill mix, industry and region. However, they admitted that this positive relationship between technology use and productivity might be reflecting the fact that good performers are more likely to use new technology than poorly performing plants. In a similar study based on the 1985 and 1991 Surveys of Production and 1992 Survey on Advanced Manufacturing Technology in the Netherlands, Bartelsman *et al.* (1996) showed that it was mostly the increase in the capital-labour ratio which improved labour productivity while the advanced technology effect was rather insignificant. On the other hand, Crépon *et al.* (1998) found positive

32. A serious limitation of this approach is that it cannot be applied for unlisted small companies or firms in the public sector.

33. In a following study using the same database, Geroski *et al.* (1993) observed that the number of innovations produced by a firm had a modest positive effect on its profitability but also that there exist substantial permanent differences in the profitability of innovating and non-innovating firms.

34. In France, Crépon *et al.* (1998) also found that the probability of a firm's engaging in R&D activities increased with its size, market share, and the degree of diversification. They used the data on some 4000 manufacturing firms in France over 1986-90.

correlation between innovation output (as measured by patent numbers or share of “innovative sales”³⁵) and firm productivity even after controlling for the skill composition of labour as well as for physical capital intensity.

III.2.2 Human capital

39. At the national level, many cross-country regression studies have examined the growth contribution of human capital using the number of years of formal schooling as a proxy for human capital.³⁶ The rate of return to education was typically estimated as the increment of wage earnings due to an additional year of schooling, based on the Mincerian approach.³⁷ At the firm level, though, training has special importance in considering the relation between a firm’s human capital investment and its performance.

III.2.2.1 Theories on training

40. Becker (1964) offered a classical theory of human capital accumulation in the form of training in general skills and training in specific skills. According to this model, firms will not pay for general training, which increases the productivity of the trainee wherever he works, since the trainee could benefit from the training by working for another employer at a higher wage. If the training firm tries to retain the employee by matching the alternative wage offers, the return from the training will go to the trainee in the form of higher wage. In this situation, the firm will have no incentives to train unless the employee bears all the costs of general training. Typically, a trainee bears the costs in the form of accepting a reduced wage during the training period.

41. Nevertheless, firm-sponsored investments in general training are widely observed in reality, contradicting Becker’s prediction. In the later models of training, some restrictive assumptions in Becker’s model were relaxed to produce more realistic predictions. For example, Acemoglu and Pischke (1998) started from an assumption that the current employer has superior information about the worker’s ability relative to other firms and considered the employer’s ex post monopsony power over the worker due to this information asymmetry. They showed that the firm in this case has incentives to invest in the worker’s human capital in the form of general training. In addition, their model points to the possibility of multiple equilibria: one with low quits and high training, the other with high quits and low training.³⁸

35. In the French Innovation Survey, the “innovative sales” is defined as sales coming from products launched in the market in the last five years.

36. While most studies in this approach suggest that education is an important factor for growth based on the observed positive correlation between schooling and growth [*e.g.* De La Fuente and Doménech (2000), Bassanini and Scarpetta (2001), among others], Bils and Klenow (2000) stresses the possibility of reverse causality. As faster growth induces more investment in physical capital, according to their view, faster growth can induce more schooling by raising the effective rate of return to investment in education.

37. One of recent results in this approach is found in Acemoglu and Angrist (1999) based on 1960-80 Census microdata in the US. Even though their estimate of private returns to education (about 7 %) is consistent with previous results in the literature, they also suggest that the social returns over and above the private returns are not significantly different from zero.

38. In a parallel paper, Acemoglu and Pischke (1999) showed that firms may want to invest in the general skills of their employees depending on wage structure, because some distortion in wage structure could make technologically general skills effectively firm specific. One important empirical implication of their model is that the true returns to training may exceed the returns to training measured in terms of the wage, whenever employers pay for training.

III.2.2.2 Training and productivity

42. There have been several attempts to explore the linkage between human capital and productivity growth using micro data. "Employee-employer matched databases" -- which combine two different data sources, one source containing information on human capital with another source for calculating firm productivity -- are used for this purpose.

43. Linking data from a survey of human-resource management (HRM) practices at the establishment level with firm-level data from the Compustat database on productivity and financial performance of listed companies in the United States, Bartel (1989) found evidence that training investment increased productivity substantially. A follow-up study by Bartel (1992) also showed that lagged training investments rather than current training had positive effects on productivity. However, the discrepancy in the unit of analysis (plant-level HRM survey combined with firm-level productivity information) and a low response rate (6%) in the HRM survey limit the reliability of the findings (Lynch and Black, 1995).

44. The conclusion from aggregate (national or sectoral) data that human capital is an important determinant of productivity was confirmed by recent studies based on micro data. For example, Black and Lynch (1996) used a large database on some 1 600 manufacturing plants and 1 300 non-manufacturing plants from the Educational Quality of the Workforce National Employers' Survey (EQW-NES), a telephone survey administered by the US Bureau of the Census. Their regression results showed that the average educational level of the establishment was positively and significantly related to productivity in both manufacturing and non-manufacturing sectors. Their results also suggested that formal training outside working hours had a positive effect on productivity in manufacturing, while computer training raised the productivity of non-manufacturing establishments.³⁹

45. Based on the Irish data from two waves (in 1993 and 1995) of surveys on 642 enterprises, Barret and O'Connell (1999) found that general training had a statistically positive effect on productivity growth, although no such effect was observable for firm-specific training. In their interpretation of the result, training which increases an individual's wage with both the existing employer and potential employers provides greater incentives for effort than training which only increases wages with the existing employer.

46. To throw light on the characteristics of firms that train their employees actively, Baldwin *et al.* (1995) using Canadian data demonstrated that technology adoption creates a need for higher skill levels and stimulates firms to train. Their regression results showed that firms that are most likely to train are those that perform R&D, are innovative, diversified, mature, foreign-owned, and have achieved strong growth. Their results suggest that the positive correlation between firm training and firm productivity may not be a simple causal relation, as skill-technology complementarity could be relevant. This is discussed further below.

III.2.3 Complementarity of technology and human capital

47. Technological progress can create a demand for workers with special skills, as well as reducing the demand for lower-skilled workers. Understanding the complementarity between technology and human capital is important in the assessment of training and education programmes for upskilling labour forces swiftly and smoothly.

39. In a follow-up study matching the above data with the Longitudinal Research Database (LRD), Black and Lynch (1997) also found that the higher the average educational level of production workers or the greater the proportion of non-managerial workers who use computers, the higher the plant productivity. See below for a discussion of linkages, if any, between computer use, wages, and productivity.

48. A large number of empirical studies imply the existence of complementarity of technology and skill (See Table 2.3). Berman *et al.* (1994) observed a positive correlation between new technology and skills upgrading from decomposing changes in the employment share of non-production workers at the level of SIC 4-digit manufacturing industries in the United States over the period 1979-89. From estimating labour demand curves for 10 occupational classes for workers based on data from a telecommunication company in the United States over the period 1980-85, Lynch and Osterman (1989) showed that technological progress shifted labour demand in favour of technical and professional employees.⁴⁰

49. As a result, users of more advanced technology appear to be rewarded better. Based on a very large database (more than 60 000 workers in 1984 and in 1989) from the Current Population Survey (CPS) in the United States, Krueger (1993) showed that workers who use a computer at work received roughly 10%-15% higher wages, other things being equal. DiNardo and Pischke (1997) found a broadly similar computer wage premium using German data. Such technology-related wage premia are not limited to computer use, but also observed from use of advanced technology in general. Combining the data from the 1988 Survey of Manufacturing Technology (SMT) and the Worker-Establishment Characteristic Database (WECD) in the United States, Doms *et al.* (1997) found that plants that use more sophisticated equipment employed more skilled workers and that workers who used more advanced capital goods received higher wages.

50. However, the existence of a causal relationship between the use of advanced new technology and higher wages remains unproved. DiNardo and Pischke (1997) pointed out that the measured wage differentials associated with other “white collar” tools such as pens are almost as large as wage premia for computer use. In their interpretation, computer users possess unobserved skills, which might have little to do with computers, or computers were first introduced in higher paying occupations or jobs. Similarly, Entorff and Kramarz (1998) found from French data that computer-based new technologies were used by workers who were already better paid even before working on these machines. Moreover, according to Doms *et al.* (1997), the most technologically advanced plants paid higher wages *prior to* adopting new technologies. These plants also were more productive, both before and after the adoption of advanced technologies. In Canada, Baldwin *et al.* (1997) also found that wages were higher in plants that adopted advanced technologies, after controlling size, age, capital intensity, diversity, and nationality. According to them, higher wages in technology-using plants reward higher innate skill levels that are required to operate the technologies and serve to attract those skills that are in short supply.

51. After reviewing the evidence from 12 countries including 10 OECD countries, Hall and Kramarz (1998) drew the following conclusions on interactions between innovation, skills, wages, and productivity. *i)* Innovative firms shift the composition of their labour force toward more skilled labour and in many cases increase overall employment as well. *ii)* The shift toward more skilled labour has often been accompanied by higher wages for skilled labour, although direct causality between use of technology and higher wages at the individual level is difficult to prove. *iii)* There is a strong correlation between productivity and advanced technology use, but it is much harder to find concrete evidence of advanced technology adoption causing productivity growth.⁴¹

40. This finding from micro-data of one specific company is consistent with findings from aggregate data such as Bartel and Lichtenberg (1987) and Autor, Katz, and Krueger (1998), among others.

41. According to their explanation, good performers adopt advanced manufacturing technology, but the consequences are difficult to trace because: *i)* they take some time to appear; and *ii)* they are accompanied by many other changes such as increases in the capital-labour ratio that confound attempts to isolate their effects on the total factor productivity in the short term.

III.2.4 Other influences on productivity

III.2.4.1 Ownership structure and productivity

52. Persistent differences in managerial ability have been considered as a plausible explanation for widely observed persistent differentials in productivity among plants/firms even in the same sector. For example, regressions by Baily *et al.* (1992), based on plant-level data with firm-identifications from the Longitudinal Research Database (LRD) in the United States, suggest that plants owned by a high-productivity firm tend to have high productivity. In their interpretation, well-managed firms can transfer their managerial skills to their plants by training managers, giving advice, transferring technology, etc.

53. Ownership changes will increase productivity if such changes produce better matches between management and firms. Several studies have tried to test this hypothesis by examining the effects of ownership changes on firms' productivity, using the Longitudinal Research Database (LRD) of the United States (Lichtenberg, 1992a; McGuckin and Nguyen, 1995). Using an unbalanced panel of some 28 000 plants in the US food manufacturing industry (SIC 20), McGuckin and Nguyen (1995) showed that: *i*) ownership change is generally associated with the transfer of plants with above average productivity; *ii*) large plants are more likely to be purchased rather than closed when they are performing poorly; and *iii*) transferred plants tend to experience improvement in productivity performance following the ownership change.⁴²

54. Ownership structure was often included as an explanatory variable in regression analyses for firm survival and firm growth, but the results are rather mixed (See Table 1.1 and Table 1.2). Interestingly, some studies found that foreign-owned firms showed higher productivity (Doms and Jensen, 1998: United States; Griffith, 1999: United Kingdom), more likelihood of training workers (Baldwin *et al.*, 1995: Canada), and higher rate of return to R&D (Dilling-Hansen *et al.*, 1999: Denmark).⁴³

III.2.4.2 Competition and international trade

55. Firm-level data have also been used to explore influences of competitive environment (such as domestic competition and foreign trade) on firm-level productivity (See Table 2.4). For example, using UK data sources Nickell (1996) and Disney *et al.* (2000) experimented with several indicators of competition in productivity regressions and concluded that competition has positive effects on productivity.⁴⁴ Nickell (1996) found that competition (measured by increased numbers of competitors or by lower levels of rents) was associated with higher productivity growth rates. Using a more recent and much larger data set of around 143 000 UK establishments, Disney *et al.* (2000) found that market competition significantly raised productivity levels as well as productivity growth rates.

56. Competition appears to be a major disciplining factor on firm performance, but not the only one. In a follow-up study by Nickell *et al.* (1997), the impact of competition on productivity turns out to be weakened when firms are under financial pressure or when they have a dominant external shareholder. This is interpreted as suggesting that the disciplining effect of competition in fact can be substituted by

42. However, one should be careful in interpreting observed positive association between ownership change and productivity, since the firms that underwent ownership change are not a random sample from the population (Bartelsman and Dom, 2000).

43. As in the case of considering the effect of ownership change, one can also question whether foreign-owned firms are a random sample.

44. The competition indicators used in these studies include: manager-based assessments, profit measures, firm concentration, market shares and import penetration.

other pressures on firms. As circumstantial evidence of the influences of competition on firms' productivity, Oulton (1998) points out that manufacturing sectors have significantly lower dispersion of productivity than the rest of the economy. A possible explanation is that manufacturing sectors are more exposed to international competition than service sectors.

57. Empirical studies using micro data generally show a positive association between exports and productivity.⁴⁵ Increasing volume of the evidence suggests that trade can contribute to aggregate productivity growth by enforcing natural selection through competition. Roberts and Tybout (1997) develop a model of exporting with sunk costs of entry. In the presence of such entry costs, only the relatively productive firms will choose to pay the costs and enter the foreign market.⁴⁶ The implied relationship between exporting and productivity is positive in a cross-section of firms or industries, but the causality runs from productivity to exporting. In other words, exporting firms show higher productivity mainly because only firms with higher productivity can enter the export market and survive there. Aw *et al.* (1997) measure differences in total factor productivity among entering, exiting, and continuing firms in Taiwan, both in the domestic and export market. Their findings suggest that both the domestic and export market sort out high productivity from low productivity firms and that the export market is a tougher screen.

58. Using plant level data from the Longitudinal Research Database (LRD), Bernard and Jensen (1999) examine whether exporting has played any role in increasing productivity growth in US manufacturing. They find little evidence that exporting per se is associated with faster productivity growth rates at individual plants. The positive correlation between exporting and productivity levels appears to come from the fact that high productivity plants are more likely to enter foreign markets, as is suggested by Roberts and Tybout (1997). While exporting does not appear to improve productivity growth rates at the plant level, it is strongly correlated with increases in plant size. Trade fosters the growth of high productivity plants, though not by increasing productivity growth at those plants.⁴⁷ According to the results of a parallel study for Germany by Bernard and Wagner (1997), sunk costs for export entry appear to be higher in Germany than in the United States, but lower than in developing countries. It is also found that plant success (as measured by size and productivity) increases the likelihood of exporting.

III.3 Firm dynamics and aggregate productivity

59. The previous two subsections discussed various aspects of firm dynamics and potential determinants of within-firm productivity growth. Productivity decomposition makes it possible to separate

45. Micro level studies in the literature have focused exclusively on the link between export and productivity, leaving the import part of the trade and productivity relationship unexplored. This is largely because micro data at the plant and firm level usually contain no information on imported inputs (Bernard and Jensen, 1999). Levinsohn (1993) is an exception which linked imports and productivity in an indirect way. Using the annual census data which cover all plants in the greater Istanbul area of Turkey from 1983 to 1986, he demonstrated that the imports-as-market-discipline hypothesis were supported by the data in the natural experiment of the broad and dramatic import liberalisation of 1984. In a similar indirect way, Bottasso and Sembenelli (2001) found a jump in productivity growth rates of Italian firms in industries where non-tariff barriers were perceived to be high, after the announcement of the EU Single Market Program (SMP: a proposal of 282 specific measures to reduce non-tariff trade barriers in the EU).

46. Based on the idea of fixed costs in entering the export market, Jean (2000) offers a model of trade under monopolistic competition with free entry and exit of heterogeneous firms. According to the model, trade-induced increase in competitive pressure can be not only import-driven but also export-driven: *i.e.* the entry of new producers attracted by the profit opportunities from exporting can intensify competition in the domestic market.

47. Very similar results were found in Clerides *et al.* (1998), which used plant-level data from Colombia, Mexico, and Morocco.

the contribution of compositional shifts to aggregate productivity growth from that of within-plant productivity growth. Even though there are different ways of splitting up productivity changes, the results generally show that aggregate productivity is significantly affected by compositional changes due to firm dynamics, *i.e.* birth and death, growth and decline of individual firms.

60. In their pioneering study decomposing aggregate productivity growth, based on the Longitudinal Research Database of the United States, Baily *et al.* (1992) found that the “between” effect was very important in aggregate productivity growth in manufacturing. According to the results of their decomposition, the increasing output shares of high-productivity plants and the decreasing shares of low-productivity plants (*i.e.* “between effect”) had a positive effect on aggregate productivity growth in all the 23 examined manufacturing industries in all three periods (1972-1977, 1977-1982, and 1982-1987). But, the contribution of entry and exit turned out to be very small and sometimes even negative. More recent studies on the same database with an improved decomposition method, however, showed that the contribution of net entry to aggregate productivity growth is also substantial, especially over a longer period (Foster *et al.*, 1998). While the “exit effect” is usually positive reflecting the fact that exiters are less productive than industry average, the “entry effect” is often negative especially when measured over a shorter time horizon. In other words, new entrants tend to be less productive than incumbents, but surviving entrants’ average productivity grows fast reflecting selection and learning effects.

61. Evidence supporting the importance of firm dynamics in explaining aggregate productivity is found in other countries as well. In the United Kingdom, such compositional changes due to firm dynamics (*i.e.* sum of “between”, “cross”, “entry”, and “exit” effects) accounted for 50% of labour productivity growth and 90% of total factor productivity growth in the total manufacturing sector over 1980-1992 (Disney *et al.*, 2000). In the Netherlands, the net entry effect turned out to be accounting for one third of aggregate labour productivity growth over the period 1980-1991. However, it should be also emphasised that decomposition results are sensitive to methods and to time periods, which makes international comparison of different decomposition results difficult. Nonetheless, some common patterns are also found. The contribution of firm dynamics to aggregate productivity growth seems to be more pronounced for total factor productivity growth than for labour productivity growth. In addition, while within-firm productivity growth appears to drive overall fluctuations in aggregate productivity growth (OECD, 2001), the contribution of firm dynamics tends to be greater during cyclical downturns (Foster *et al.*, 1998). In Korea, for example, net entry effects accounted for 45% of aggregate TFP growth during cyclical upturn (1990-1995) and 65% during cyclical downturn (1995-1998) (Hahn, 2000).

IV. Firm Dynamics and Productivity in the Service Sector

62. In most OECD countries, the service sector accounts for over 60% of the economy in terms of both value added and employment, and the share has been increasing (OECD, 2000*b*). The fact that the service sector accounts for a larger share of output and employment than manufacturing in most OECD countries underlines the necessity of better understanding productivity evolution in the service sector. Unfortunately, due to data constraints as well as methodological difficulties in measuring service sector productivity, most studies on firm dynamics and productivity have so far focused on the manufacturing sector.

IV.1 Measurement problems and conceptual issues

63. Measurement problems are more intractable in the service sector than in manufacturing partly because of data problems but more importantly because of a conceptual problem (Griliches, 1992). Various conceptual problems arise from the fact that services are intangible. In many service sectors, it is hard to define and quantify what is being transacted, what is the output, and what services correspond to the payments made to their providers. Censuses and annual surveys of service industries started rather recently

even in the United States, and they are much less detailed than those of the manufacturing sectors in their coverage of inputs used. Many of the service industries produce intermediate products in areas with very little direct price coverage (*e.g.* computer programming, advertising, information, etc.). Due to the lack of data and/or due to conceptual difficulties, real output in a number of service industries is assumed to grow proportionally to some measure of input, eliminating by assumption any possibilities of measured productivity growth.

64. The usual way of measuring the real output of an industry is to deflate a nominal measure of output for the industry with a price index for the industry's product. Measuring service output also involves the following two stages:

- Identifying the unit of output.
- Adjusting for the variation in quality.

Accounting for variation in quality is very difficult especially when the unit of service is hard to define. Difficulties in defining the unit of service have different sources as follows (Sherwood, 1994):

- Enumerating the elements of a complex bundle of services (*e.g.* retail trade industry⁴⁸).
- Choosing among alternative representations of an industry's output (*e.g.* in the case of the banking industry, whether to incorporate demand deposits as inputs, or outputs).
- Accounting for the consumer's role in the generation of a service output (*e.g.* if a band plays to an empty stadium, one can say that there is no output because there are no consumers).

65. Some recent studies tried to obtain a better measure of productivity in service industries by using more direct output measures, for example:

- Banking industry: number of cheques processed or cleared per hour.
- Airline industry: passenger-miles (or passenger-kilometres).
- Legal services: number of wills prepared per year.
- Health industry: number of procedures performed per year.

In many cases, the use of these direct indices of service output resulted in higher measured productivity growth than indirect measurement of output via input measures. However, the use of these direct measures can be also criticised on the ground that they usually capture only one or several aspects of a composite service output and often the least important parts of the industry's activity (Wolff, 1999).

IV.2 Findings from service sectors

66. In spite of methodological difficulties and data constraints, a growing number of empirical studies in the literature have explored firm dynamics and productivity growth in the service sector. Selected studies from this growing body of literature are reviewed here.⁴⁹

48. The bundle of services provided by a retailer includes: consummating transactions; assembling, displaying, and providing information on goods; making the goods available at times and places convenient to customers; supplying additional services such as delivery and credit; and packaging and processing goods into more suitable forms, etc.

IV.2.1 Firm dynamics

67. Using the database from the National Institute for Social Security (INPS) in Italy, Santarelli (1998) examined more than 11 000 new firms in the tourist industry (hotels, restaurants, and catering firms) with at least one paid employee in 1989 and tracked them over the subsequent five years. He found that there existed a significantly positive association between start-up size and the likelihood of survival, confirming the pattern repeatedly observed in the manufacturing sector in many countries. His results also showed a \cap -shaped hazard function with a peak at the second year of the activity.⁵⁰

68. Using the Dutch data based on annual surveys by Statistics Netherlands (CBS), Audretsch *et al.* (1997) analysed firm dynamics in the retail and “hospitality” (hotels, restaurants and catering) sectors. They started with about 13 000 new-firm start-ups and 47 000 incumbents in these service sectors in 1985 and tracked them for the period 1985-1988. Annual observations for each firm included the number of employees, the year the firm was started, the municipal location, the four-digit industry code (SBI), the firm identifier, etc. According to their results, one of the main differences between services and manufacturing, at least in the Netherlands, is the absence of scale economies in services. The relationship between firm survival, growth, age, and size, which are observed so consistently in manufacturing did not exist in the service sector for all but the smallest firms. For Canada, Hamdani (1998) compared the service sector with the goods sector using the Longitudinal Employment Analysis Program (LEAP) database. The study found that the service sector is more volatile (measured by the sum of entry and exit rates) than the goods-producing sector.

IV.2.2 Productivity correlates

IV.2.2.1 Ownership structure

69. The effects of mergers in the US airline industries have been an important topic for researchers. Using data on 25 airlines for 1970-84 and 10 start-up airlines for 1982-84, Lichtenberg and Kim (1989) found that the average annual rate of unit cost growth of carriers undergoing mergers was 1.1% lower, during the 5-year period centred on the merger, than that of carriers not involved in merger. According to their results, part of the cost reduction is attributed to merger-related declines in the prices of inputs, particularly labour, but about 2/3 of it is due to increased total factor productivity. One source of the productivity improvement is an increase in capacity utilisation (*i.e.* load factor).⁵¹

70. Ehrlich *et al.* (1994) estimated a cost function and TFP growth for 23 international airlines with varying levels of state-ownership. Their point estimates of the ownership effects suggest that a shift from complete state ownership to full private ownership would increase the *long-run* annual rate of TFP growth by 1.6-2.0% and the rate of unit cost would decline by 1.7-1.9%. However, based on the separation of

49. For a review of empirical studies on the effects of regulatory reform on service productivity, especially focused on cross-country studies, see Nicoletti (2001).

50. A parallel study on manufacturing firms based on the same INPS database (Audretsch *et al.*, 1999) showed that there was a significantly negative correlation between the growth rate and the initial size while no link was found between start-up size and survival. In the Italian manufacturing sector, the hazard function was also found to be \cap -shaped with a peak at the second year.

51. On the other hand, Kim and Signal (1993) estimated relative fare changes in 21,351 routes affected by 14 airline mergers during the 1985-1988 period and found significant increases in airfares in the routes affected by mergers relative to the control group. Their conclusion was that the impact of efficiency gains on airfare was more than offset by exercise of increased market power.

static from dynamic differences in productive efficiency, they add that productivity *level* differences may be inconclusive in the *short run*.

IV.2.2.2 Regulation

71. Negative effects of regulations on efficiency in the *distribution sector* in OECD countries were analysed by Høj *et al.* (1995). Their regression results based on cross-country comparison of the average size of retail establishments suggest that the removal of entry-restricting regulations on large-scale outlets could lead to substantial efficiency gains in the distribution sector and to some potential gains including reduced consumer price.⁵²

72. Measuring the impact of regulatory reform in the *airline industry* is a complicated task. Based on translog variable cost function regressions using an unbalanced panel of 293 observations from 24 airlines over the period 1971-86, Baltagi *et al.* (1995) concluded that, despite the slowdown of productivity growth in the 1980s, deregulation did appear to have stimulated technical change due to more efficient route structures. Marín (1998) extended the scope to include 10 European flag carriers in addition to 9 US companies and estimated a stochastic production frontier to measure technical efficiency. According to his results, the introduction of liberalisation in the form of bilateral agreement with the US has brought about a short run reduction in efficiency that is expected to be followed by long run efficiency improvements. Possible reasons for this short run efficiency loss include: *i*) Firms may decide to use more productive inputs which require some time before being efficiently utilised; and *ii*) Re-organisation of their output cannot be immediately followed by adjustments in their input requirement.⁵³

73. According to a meta-study on the effects of liberalisation on the *road freight industry* based on aggregate data from selected OECD countries, liberalisation in this sector has raised business entry rates, reduced prices while improving the service quality, and has improved industry efficiency (Boylaud, 2000). In addition, competition tends to eliminate rents for the employees of incumbent firms that have been created by barriers to entry and restrictions on price competition. Using micro data from Current Population Surveys (CPS) by the US Bureau of Census over the period 1973-85, Rose (1987) found that union premiums over non-union wages in the US trucking industry had declined by roughly 40%, beginning in 1979 when deregulation started.⁵⁴

74. In a recent study on the relationship between competition and productivity growth in the US *telephone industry*, Gort and Sung (1999) constructed the output index in a conventional way by deflating revenues of a telephone company by appropriate price indices. Comparing the performance (in terms of both productivity and cost) of AT&T Long Lines, operating in an increasingly competitive markets, with that of eight local telephone monopolies, the study concluded that competition is conducive to productivity growth. Over the 1985-91 period, TFP growth rate of AT&T Long Lines was 7-14 times larger than that of the regional companies.

52. Parenthetically, regulation indicators in the retail distribution sector calculated based on factor analysis show that countries with most stringent regulations as of 1998 were France, Japan, Greece, and Austria, while the Czech Republic, Switzerland, and Australia appeared to have most liberal environment (Boylaud, 2000). For the general framework of the OECD product market regulation indicators, see Nicoletti *et al.* (1999).

53. Based on the aggregate level data for 27 OECD countries and the micro-level data for 102 air routes connecting 14 major international airports, Gonenc and Nicoletti (2000) also found that efficiency and fares are affected by regulatory and market arrangements.

54. Supporting evidence of the “rent-sharing” hypothesis was also found in the UK by Hildreth and Oswald (1997), amongst others.

75. While Fixler and Zieschang (1992) estimated that the banking output index rose by 8.8% per year during 1984-88, Berger and Humphrey (1992) also evaluated the performance of the US *banking industry* over the period 1980-88 by estimating multiple-equation thick-frontier cost functions. But, their results showed that operating cost dispersion and inefficiency rose substantially over the period, particularly from 1984 to 1988, which was interpreted as implying a less than complete adjustment to the new, less regulated equilibrium.

IV.2.3 *Productivity decomposition*

76. Foster *et al.* (1998) applied labour productivity growth decomposition analysis on a selected service industry (automotive repairing: SIC 753) in the United States, based on the data from Census of Services. The results showed that net entry played a very large role in this selected service industry (substantially larger than in manufacturing) regardless of the decomposition method used. In fact, the contribution to productivity growth from net entry exceeded the overall industry growth, meaning that the overall contribution of continuing establishments was negative.

77. Another productivity growth decomposition analysis was made by Van der Wiel (1999), for the business services sector in the Netherlands using the data from annual surveys by Statistics Netherlands (CBS) over the period 1988-95. This study confirmed findings of other recent studies that there is a tremendous reallocation of activities across firms, especially in services. It was also found that changes in market shares, relatively low productivity levels of entrants, and lack of productivity improvement by incumbents were important factors that held back labour productivity growth in the business services sector.

V. **Summary**

78. The main conclusions drawn from the empirical literature can be summarised as follows:

Firm dynamics

- Descriptive statistics of firm dynamics in different OECD countries in different periods consistently show that a substantial number of firms enter and exit from each sector each year.
- Small entrants have a low probability of survival on average unless, having passed the initial test of market competition, they grow rapidly to a reasonable size.
- In the early stage of product life cycle, new entrants play a particularly important role perhaps because they can be more aggressive with experimenting new technology. Firm turnover rates are higher under more innovative and more competitive environments.

Productivity correlates

- Both technology and human capital of workers appear to influence firm-level productivity. Innovative firms tend to shift the composition of their labour force toward more skilled labour through recruiting and training, and such shifts are often accompanied by higher productivity and higher wages for skilled labour.
- A direct causal link between technology or human capital and productivity at the individual level is difficult to prove, while evidence of technology-skill complementarity is widely

observed. Both advanced technology use and higher wages may well be a result of a third factor (*e.g.* better management).

- Findings from micro data suggest that ownership structure is an important determinant of firm-level productivity. Likewise, exposure to competition, including international trade, plays a very important role in selecting high productivity firms.

Productivity decomposition

- There are large and persistent differences in productivity levels across producers even in the same industry, and inputs and outputs are constantly reallocated from less efficient ones to more efficient ones through firm dynamics. Aggregate productivity growth come from firm dynamics as well as from within-firm productivity growth.
- The contribution of firm dynamics to aggregate productivity appears to be more pronounced for total factor productivity growth than for labour productivity growth. While within-firm productivity growth seems to drive overall fluctuations in aggregate productivity growth, the contribution from the exit of low-productivity units increases its importance during cyclical downturns.

Firm dynamics and productivity growth in the service sector

- In spite of the large and still increasing share of the service sector in most OECD countries, difficulties in measuring service productivity have obliged most studies on firm dynamics and productivity growth to be focused on manufacturing. Emerging empirical studies suggest that firm dynamics are more volatile and more important for explaining aggregate productivity growth in the service sector than in the manufacturing sector.

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ANNEX ON MICRO DATA SETS

Empirical studies on firm dynamics and productivity growth in the literature are based on data from various different sources. Data sources include business registers, production census data, and various statistical surveys (on R&D, advanced technology use, employment, labour force, training, etc.). Oftentimes, firm entry and exit are inferred from the appearance and disappearance of plant- and/or firm-identification codes. Those plant- or firm-identifiers are also crucial for: *i*) tracking individual business units over time to construct a longitudinal data base; and *ii*) linking more than one data sources (for example, linking production census with innovation survey, constructing employer-employee database, etc.).

A. Selected data sets based on business registers and production census

- The *Longitudinal Research Database (LRD)* developed by the Center for Economic Studies (CES) at the Census Bureau of the United States is one of the best-known longitudinal micro-level databases. It was constructed by pooling information from the Census of Manufactures (CM) and from the Annual Survey of Manufactures (ASM). Contained information includes: shipments, materials, inventories, employment, wages, energy use, investment, capital (structures and equipment in book value), capital rentals, ownership structure, etc. (Baily *et al.*, 1992)
- The *Annual Census of Production Respondents Database (ARD)* of the United Kingdom is similar to the Longitudinal Research Database (LRD) of the United States but it started to be used by researchers more recently (Oulton, 1997; Griffith, 1999; Disney *et al.*, 2000). The ARD is based on business registers where the unit of observation is an address called “local unit”. If a local unit is large enough to provide information on the full Census questionnaire, it is termed an “establishment”. If a local unit is a head office of one or more establishments under common ownership or control, it is called an “enterprise group”. Three identification numbers are assigned to each address, identifying it as local unit, establishment and enterprise group. One weakness of the ARD is that smaller establishments (with employment below 100 persons) have been sampled with frequently changing sampling methods.
- A longitudinal file of annual data in Canada constructed from the Census of Manufactures tracks plants since 1970 and links plants to firms (Baldwin and Rafiquzzaman, 1995). Since firm-identifiers in census data are not necessarily created or maintained with longitudinal analysis in mind, it can happen that the statistical office reassigns identifiers to continuing plants, thereby creating false births and deaths. But, this does not seem to have created a serious problem in case of Canada (Baldwin and Gorecki, 1990).

B. Selected employment-related data sets

- An example of employment database is found in Boeri and Bellmann (1995), who used the data from the Employment Statistics register of the Federal Office of Labour (Bundesanstalt für Arbeit: BA) in Germany. The register covers all dependent employment in the private sector. Individual plants are assigned separate identification numbers even when they belong to the same firm. This makes it possible to trace histories of individual establishments, and hence to analyse the post-entry behaviour of different cohorts of units. Plant openings and closures are identified by comparing the number of employees of each plant at different points in time. Entrants [exiting units] are establishments which had no [some] registered workers at t , but some [no] dependent employees at $t + 1$. A main advantage of BA data with respect to other longitudinal data used in the analysis of the post-entry performance of business units is that there is little, if any, under-sampling of small and young establishments.
- Mata *et al.* (1995) also used an employment-focused database derived from the *Quadros do Pessoal* of the Portuguese Ministry of Employment (MESS). Information on all companies operating in Portugal has been collected on a yearly base since 1981, through a mandatory questionnaire.⁵⁵ This information is gathered at branch-level and includes both plant- and firm-specific characteristics. The MESS provides a unique identifier for the parent company and respective plants for all the inquirers and thoroughly checks their accuracy. As usual, a plant was defined as ‘born’ in a given year if that was the first year it appeared in the database. Some plants could be erroneously classified as births if the plant was already operating but it had not previously reported to the survey. To avoid misclassifying plants as ‘new’, they imposed the condition that, at the time of birth, the tenure of the longest tenured employee could not exceed 1 year. Similarly, they defined a plant ‘death’ as occurring in the year for which no further record exists of its activity.⁵⁶ The final data set consists of seven different cohorts of new plants, covering the 1983 to 1989 period.

C. Other databases

- The *Small Business Database (SBDB)* from the US Small Business Administration was widely used in analysing post-entrance performance of new firms in the United States.⁵⁷ Businesses are identified at both the establishment and enterprise levels by the SBDB. Observations were reported once every two years between 1976 and 1986. The SBDB identifies start-ups of new firms and establishments and allows tracking the subsequent performance of these entrants over time. Therefore, one can tell whether an establishment in the SBDB is *i)* a single-establishment firm, *ii)* a branch or subsidiary of a multi-establishment firm, or *iii)* the headquarter of a multi-establishment firm. The individual records in the SBDB are derived from Dun & Bradstreet, whose records are biased toward covering only those establishments and single plant firms that need to establish credit ratings. According to Acs and Audretsch (1990, Chapter 2), however, the patterns that the SBDB yields agree with those based on data from official census records.

As a good example of a study based on more than one data source, Doms *et al.* (1995) used three establishment-level data sources in the United States: the 1987 *Census of Manufactures (CM)*; the 1988

55. Family businesses without wage-earning employees are not covered in this data source.

56. To deal with the problem of temporary exits, they adopted the following procedure. Plants which exit in a single period were considered to be alive in that period, and their employment was imputed as the average the plants’ employment in the previous and the subsequent years. Those plants whose temporary exit was greater than 1 year were excluded from the data base.

57. For example, Audretsch (1991, 1995), Evans (1987), and Audretsch and Mahmood (1994, 1995) used SBDB.

Survey of Manufacturing Technology (SMT); and the 1991 *Standard Statistical Establishment List (SSEL)*. The CM provided the basic data on output and inputs to construct the plant-level productivity statistics (labour productivity and TFP) and capital intensity measures in 1987. The SMT provides information on each plant's usage of 17 different advanced production technologies at the beginning of 1988. The SSEL is used to track plants over time. The 1991 SSEL is a complete list of all establishments in the US. Plants in the 1988 SMT that are not found in the 1991 SSEL were considered potential exits between 1988 and 1991.⁵⁸

58. As the 1988 SMT includes only those plants whose total employment was greater than 20 in the 1987 CM, the smallest manufacturing plants were omitted from the analysis.

Table 1.1 Influences on firm survival/exit

Author	Country	Sample year	Sample	Dependent variable	Explanatory variables							Comments
					Firm size	Firm age	Productivity	Technology/Innovation	Capital	Ownership structure	Others	
Dunne, Roberts and Samuelson (1989a)	US	1967, 1972, 1977	219 754 plants in 1967, 1972, 1977 census (employees ≥ 5)	Plant failure rate of a cell grouped by size, age, industry, year, and ownership structure	Negative	Negative	—	—	—	Negative effect of plant size is less apparent for single-unit plants	—	Plant is grouped by: three age categories, five current size classes, 20 2-digit SIC industries, two ownership categories, and three initial size classes.
Doms, Dunne, and Roberts (1995)	US	1987, 1991	6 090 plants (employees ≥ 20)	Probability of exit (Probit model)	Negative	Negative	Negative	Negative (Insignificant if size is controlled)	Plant capital-intensity having negative on exit	—	—	Dummies for classes in size, age, and advanced technology usage
Audretsch and Mahmood (1994)	US	1976-1986 (bi-annual)	7 070 new entrants in 1976	Probability of exit (Hazard model)	Startup size having negative effect	Inverse U-shaped hazard function is implied	—	Hazard rate is higher in more innovative industries	—	New-firm start-ups are much more influenced from the environment than new branches of existing firms	- MES (minimum efficiency scale) raises hazard rate - Industry growth lowers hazard rate	Partial likelihood estimation based on proportional hazard model
Audretsch and Mahmood (1995)	US	1976-1986 (bi-annual)	12 251 new entrants in 1976	Probability of exit (Hazard model)	Startup size having negative effect	—	—	Innovation rate of the industry having positive effect on hazard rate	Overall capital-intensity of the industry raises hazard rate	Ownership structure affects hazard rate	Macro-economic downturns (e.g. unemployment rate) raise hazard rate	Partial likelihood estimation based on proportional hazard model

Table 1.1 Influences on firm survival/exit (continued)

Author	Country	Sample year	Sample	Dependent variable	Explanatory variables							Comments
					Firm size	Firm age	Productivity	Technology/Innovation	Capital	Ownership structure	Others	
Audretsch (1995b)	US	1976-1986	11 322 new-firm entrants in 1976	Probability of survival (Logit model)	Positive	—	—	Industry innovation is negative on survival rate for new entrants, but not for long-term (8-year) survivors.	—	Multi-plant entry has lower survival rate (due to overstated firm size)	- MES (minimum efficient scale) proxy (negative) - Industry growth (positive)	
Honjo (2000)	Japan	1986-1994	2 488 firms in Tokyo founded during 1986-1994	Probability of business failure (Hazard model)	Negative	Positive until 6 th year (Inverse U-shaped hazard function)	—	—	Size of paid-up capital reduces hazard rate	—	- Industry entry rate (positive) - Entry year dummy	Partial likelihood estimation based on proportional hazard model, using "age" and "calendar time"
Wagner (1994)	Germany (Lower Saxony)	1979-1990	4 entry cohorts (1979-1982) of single firms	Probability of survival (Probit model)	Positive (only for 1979 and 1992 cohorts)	—	—	—	—	—	Industry variables (e.g. concentration, R&D-intensity, growth) are mostly insignificant)	
Boeri and Bellmann (1995)	Germany	1978-1992	2 cohorts of new plants (1979 and 1982 cohorts)	Probability of exit (Logit model)	—	Negative	—	Negative	—	—	- Congestion at entry (mostly positive but insignificant) - Profit (negative) - Cyclical factors (insignificant)	
Audretsch, Santarelli and Vivarelli (1999)	Italy	1987-1993	1 576 firms born in January 1987	Probability of survival (Logit model)	Not significant	—	—	—	—	—	—	Univariate regressions on start-up size (and constant term), with 20 industries

Table 1.1 Influences on firm survival/exit (continued)

Author	Country	Sample year	Sample	Dependent variable	Explanatory variables							Comments
					Firm size	Firm age	Productivity	Technology/Innovation	Capital	Ownership structure	Others	
Dunne and Hughes (1994)	UK	1975-1985	2 000+ firms	Probability of survival (Probit model)	Larger firms with slow growth are more likely to survive than smaller firms with slow growth	—	—	—	—	—	—	Univariate regressions on net asset growth (and constant term), with three size classes (small, medium, large)
Disney, Haskel, and Heden (2000)	UK	1980-1992	22, 000 observations on all cohorts of plants born between 1980 and 1990	Probability of exit (Hazard model)	Negative (insignificant)	—	Negative	—	—	Single-plant firms tend to have lower hazard rates	—	
Salvanes and Tveteras (1999)	Norway	1977-1992	11 174 plants (employees ≥ 5)	Probability of exit (Probit model)	Negative	Plant age (negative) Capital age (positive)	—	—	—	—	Profitability (negative) Sensitive to cyclical factors	
Mata and Portugal (1994)	Portugal	1982-1988	3 169 entrants	Probability of exit (Hazard model)	Negative	Negative	—	—	—	Multi-plant entrants tend to survive longer	- Industry entry rate (positive) - Industry growth rate (negative)	Cox Proportional Hazard Model, as well as ordered logit (and probit), applied
Mata, Portugal and Guimarães (1995)	Portugal	1982-1992	7 cohorts of new plants from 1983 to 1989	Probability of exit (Hazard model)	Negative	Negative	—	—	—	Multi-plant firms are more likely to close plants	- Industry entry rate (positive) - Industry growth rate (negative)	- 7 cohorts of new plants (1983-1989) were tracked until 1992 - Cox Proportional Hazard Model applied

Table 1.2 Influences on firm growth

Author	Country	Sample year	Sample	Dependent variable	Explanatory variables							Comments
					Firm size	Firm age	Productivity	Technology/Innovation	Capital	Ownership structure	Others	
Dunne, Roberts and Samuelson (1989a)	US	1967, 1972, 1977	219 754 plants in 1967, 1972, 1977 census (employees ≥ 5)	Mean growth rate of non-failing plants in a cell grouped by age, size, industry, year, and ownership structure	Negative	Negative	—	—	—	Survivors grow faster in multiunit plants than in single-unit	—	Plant is grouped by: 3 age categories, 5 current size classes, 20 2-digit SIC industries, 2 ownership categories, and 3 initial size classes.
Audretsch (1995b)	US	1976-1978	8 300 new-firm entrants in 1976 which survived until 1978	Employment growth	Negative	—	—	Positive	—	Multi-plant entry has higher growth rate (due to over-stated firm size)	- MES (minimum efficient scale) proxy (positive) - Industry growth (positive)	
Doms, Dunne, and Roberts (1995)	US	1987, 1991	6 090 plants (employees ≥ 20)	Employment growth rate	Negative	Negative	Positive	Positive	Positive	—	Estimated inverse Mills ratio to control selection bias	Dummies for classes in size, age, and advanced technology usage
Boeri and Bellmann (1995)	Germany	1978-1992	2 cohorts of new plants (1979 and 1982 cohorts)	Survivors' average employment growth rate	—	Negative	—	Not significant	—	—	Neither profit nor cyclical conditions significant	
Audretsch, Santarelli, and Vivarelli (1999)	Italy	1987-1993	1 576 firms born in January 1987	Survivor's growth in net assets (final net asset size)	Negative (with start-up size)	—	—	—	—	—	—	Univariate regressions on start-up size (and constant term), in selected industries

Table 1.2 Influences on firm growth (continued)

Author	Country	Sample year	Sample	Dependent variable	Explanatory variables							Comments
					Firm size	Firm age	Productivity	Technology/Innovation	Capital	Ownership structure	Others	
Dunne and Hughes (1994)	UK	1975-1985	2 000+ firms	Survivor's growth in net assets (current net asset size)	Negative	Negative	—	—	—	—	—	Sample selection model and OLS estimates have turned out to be very similar
Baldwin and Rafiquzzaman (1995)	Canada	1970-1989	Green-field entry cohorts for the years 1971 to 1982	Growth rate of the entry cohort over the first ten years of life	Size of surviving entrants relative to exiting entrants as a measure of severity of selection (positive)	—	Labour productivity growth of surviving entrants relative to incumbents as a measure of evolutionary learning (positive)	—	—	—	- Concentration index (positive) - Initial cost disadvantage (positive)	

Table 2.1 Technology, innovation and productivity: selected studies

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Baldwin and Diverty (1995)	Canada	1989	All manufacturing industries (sample of 3 952 plants)	- Canadian Census of Manufactures - 1989 Survey of Manufacturing Technology (SMT)	Regression analysis (technology use on plant characteristics)	- Plant size and plant growth are closely related to both the incidence and the intensity of technology use. - Foreign ownership and R&D activities are also closely related to using advanced technology.
Baldwin, Gray, and Johnson (1995, 1997)	Canada	1989, 1993	All manufacturing industries (3 952 plants from 1989 SMT; 2 877 from 1993 SIAT)	- Canadian Census of Manufactures (1980-1989) - 1989 Survey of Manufacturing Technology (SMT) - 1993 Survey of Innovation and Advanced Technology (SIAT)	Regression analysis (probability of the plant offering training on technology use and other plant characteristics; wage rate on technology use and other plant characteristics)	- Technology adoption creates a need for higher skill levels and stimulates firms to train. - Firms that are most likely to train are those that perform R&D, are innovative, diversified, mature, foreign owned, and have achieved strong growth. - Wages are higher in plants that adopt advanced technologies, after controlling size, age, capital intensity, diversity, and nationality. - Higher wages in technology-using plants reward higher innate skill levels that are required to operate the technologies and serve to attract those skills that are in short supply.
Dilling-Hansen, Eriksson, Madsen, and Smith (1999)	Denmark	1993, 1995	226 manufacturing firms	- Accounting data from a private company (<i>Kobmandsstandens Oplysningsbureau Ltd.</i>) - R&D Statistics by the Ministry of Research - Innovation Survey	Regression analysis (estimating a production function with R&D capital)	- Positive output elasticity of R&D capital (12-15%) - Foreign-owned firms' R&D capital is associated with greater return than domestic firms.
Crépon, Duguet, and Mairesse (1998)	France	1986-1990	6 145 firms (among which 4 164 firms responded to the Innovation Survey)	- Unified System of Enterprise Statistics (SUSE) files - Survey on the Structure of Employees (ESE) - Annual Survey of Enterprises - Annual Survey on Enterprise R&D - European Patent (EPAT) database - 1990 Innovation Survey (by SESSI)	Regression analysis (estimating research equation, patent equation, innovation equation and productivity equation in reduced form and/or structural form)	- The probability of a firm's engaging in research (R&D) increases with its size (number of employees), its market share and diversification, and with the demand-pull and technology-push indicators. - The research effort (R&D capital intensity) of a firm engaged in research increases with the same variables, except for size (its research capital being strictly proportional to size). - The firm innovation output (measured by patent numbers or innovation sales) rises with its research effort. - Firm productivity correlates positively with a higher innovation output, even when controlling for the skill composition of labour as well as for physical capital intensity.

Table 2.1 **Technology, innovation and productivity: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Hall and Mairesse (1995)	France	1980-1987	- Unbalanced panel of 351 manufacturing firms (1971–1987) - Balanced panel of 197 firms x 8 years (1980-1987): 1 576 observations	- Annual Survey on Enterprise R&D (by the Ministry of Research and Technology) - Annual Survey of Enterprises (by INSEE) - Unified System of Enterprise Statistics (by INSEE)	Regression analysis (estimation of R&D contribution with various specifications)	- The coefficient of R&D capital in the production function is uniformly positive for the different specifications and the different types of estimates. - The level of R&D capital is correlated with permanent firm or industry effects, which implies substantially higher coefficients in the cross-section dimension than in the time-series dimension.
Piergiovanni, Santarelli, and Vivarelli (1997)	Italy	1978-1986, 1989	Regional data on 20 regions (1978-1986) and 46 provinces (1989) (291 innovating firms out of 530, grouped into three firm-size classes by number of employees)	- Longitudinal database by Franco Malerba at Bocconi University of Milan (constructed by breaking down Italian patents extended to the US by region of innovating firm) - National Statistical Institute of Italy (ISTAT) - Product Innovations Database (PRODIN89) by Santarelli and Piergiovanni - University research expenditures database by the Commissione Tecnica per la Spesa Pubblica	Regression analysis (number of innovations in the region on regional R&D expenditures and university research expenditures, both with all firms and also with three subsamples by firm-size class)	Spillovers from university research are a relatively more important source of innovation in small firms, while spillovers from industrial research are more important in producing innovation in large ones.
Odagiri (1983)	Japan	1969-1981	370 manufacturing firms listed on Tokyo Stock Exchange (Market 1*) from 1966 through 1980 * Market 1 has stricter listing requirements and hence lists large, well-known companies.	Company financial reports	Regression analysis (sales growth rate on R&D and patent loyalty variables)	- Positive effect of research on firm growth was confirmed only among firms in R&D intensive industries such as chemical, pharmaceutical, electronic equipment, and precision equipment industries. - The effect on firm growth of patent license payment was dubious.
Motohashi (1998)	Japan	1991	Every firm with no less than 50 employees and ¥ 30 million of capital in manufacturing (13 685 firms)	Basic Survey of Business Structure and Activities (BSBSA) by MITI	Regression analysis (R&D expenditures on sales and firm size variables; TFP on R&D and patent-related variables)	- R&D variables are skewed to larger firms. Skewness of R&D expenses in Japan seems to be larger than that in the US. - Productivity difference across firms within an industry can be explained partly by the degree of firm's commitment to R&D activities, and this relationship is observed especially in high-tech in-house R&D group.

Table 2.1 **Technology, innovation and productivity: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Odagiri and Iwata (1986)	Japan	1966-1982	311 manufacturing firms listed on Tokyo Stock Exchange (Market 1) from 1966 through 1983	NEEDS financial data tape by Nihon Keizai Shimbunsha (Nikkei)	Regression analysis (estimating the rate of return on R&D stock)	The rate of return on R&D stock is estimated to be 20% in 1966-1973 and 17% in 1974-1982, but is found to decrease when industrial dummies or the rate of deflated sales growth is added as an explanatory variable.
Bartelsman, Leeuwen, and Nieuwenhuijsen (1996)	Netherlands	1985, 1991	All firms with more than 10 employees (6 121 firms which existed both in PS85 and PS91, among which 1 435 firms responded to 92AMT)	- 1985 Survey of Production (PS85) - 1991 Survey of Production (PS91) - 1992 Survey of Advanced Manufacturing Technology (AMT92)	Regression analysis (probability of adopting AMT on firm characteristics; employment and productivity growth on AMT)	- The probability that a firm used AMT equipment increased with firm size and capital-labour ratio. - Firms which use AMT have higher employment growth on average. - Labour productivity growth increases by about 0.5% more per year for the AMT using firms than for others, but on average, the AMT effect is insignificant.
Bartelsman, Leeuwen, Nieuwenhuijsen and Zeelenberg (1996)	Netherlands	1985, 1989, 1993	382 firms in 1985; 436 firms in 1989; and 347 firms in 1993 (209 firms in both 1985 and 1989; 159 firms in both 1989 and 1993)	- Extended R&D Surveys of 1985, 1989, and 1993. - Annual production surveys.	Regression analysis (estimation of R&D contribution with various specifications)	- The elasticity for the R&D capital stock is about 0.06 for gross output and 0.08 for value added and the private gross rate of return to R&D varies between 12% for gross output and about 30% for value added. - These results are very similar to the ones from France by Hall and Mairesse (1995).
Geroski, Machin, and Van Reenan (1993)	UK	1972-1983	721 manufacturing firms observed over the period 1972-1983 (of which 117 firms produced at least one innovation during that period)	- Datastream databank (database of information on firms listed in London Stock Exchange) - The Science Policy Research Unit (SPRU) innovations database	Regression analysis (profit margin on firm innovation, industry innovation, market share, etc.)	- Number of innovations produced by a firm has a positive effect on its profitability, but the effect is on average rather modest in size. - Observed spillovers associated with the innovations in the data are relatively small and very imprecisely estimated. - The profit margins of innovating firms are less sensitive to cyclical downturns than are those of non-innovators.
Van Reenen (1997)	UK	1976-1982	598 manufacturing firms	- Datastream on-line service and EXSTAT - The Science Policy Research Unit (SPRU) innovations database - Patents granted to UK firms by the US Patent Office between 1969 and 1988	Regression analysis (employment levels/changes on innovation and patent variables)	- Technological innovation was associated with higher firm-level employment. This result seemed robust to a wide range of specifications and controls. - Although the data show that big firms innovate most, even after using long lags on innovation and controlling for firm-fixed effect there is evidence of correlation between employment and innovation. - Another interesting finding was the absence of spillovers or employment externalities from other firms in the industry.

Table 2.1 **Technology, innovation and productivity: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Doms, Dunne, and Roberts (1995)	US	1987, 1991	Selected 5 (SIC 2-digit) manufacturing industries (6 090 Manufacturing plants with employees \geq 20)	- 1987 Census of Manufactures (CM) - 1988 Survey of Manufacturing Technology (SMT) - 1991 Standard Statistical Establishment List (SSEL)	Regression analysis (exit / plant growth on technology use)	Capital-intensive plants and plants employing advanced technology have higher growth rates and are less likely to fail.
Doms, Dunne, and Troske (1997)	US	1977, 1982, 1987, 1992	Selected 5 (SIC 2-digit) manufacturing industries + Employer-employee matched database (final data set in the study contains 34 034 worker records matched to 358 plant records)	- Survey of Manufacturing Technology (SMT: 1988, 1993) - Worker-Establishment Characteristic Database (WECD) - Longitudinal Research Database (LRD)	- Cross-tabulation of the education level and occupation mix of workers by the number of advanced technology in plants - Regression analysis (changes in the nonproduction labour share, wages, and labour productivity)	- Plants that use more sophisticated capital equipment employ more skilled workers, and workers who use more sophisticated capital receive higher wages. - However, the most technologically advanced plants paid their workers higher wages prior to adopting new technologies, and these technologically advanced plants are high productivity plants both pre- and postadoption.
Dune (1994)	US	1987	Selected 5 (SIC 2-digit) manufacturing industries	- 1987 Census of Manufactures (CM) - 1988 Survey of Manufacturing Technology (SMT)	- Cross-tabulation of technology usage by plant size and age - Regression analysis (technology usage probits for each 3-digit industries)	- Both old and young plants appear to use advanced manufacturing technology at similar frequencies. - Larger plants are more likely to employ newer technologies than are smaller plants.
Krueger (1993)	US	1984, 1989	Employed population (61 712 workers in 1984; 62 748 workers in 1989)	- Current Population Surveys (CPS) in 1984 and in 1989 - High School and Beyond Survey (HSBS)	Regression analysis (wage on computer-use dummy, years of education, experience, etc.)	- Workers are rewarded more highly if they use computers at work. Workers who use a computer earn roughly 10-15% higher pay, other things being equal. - The expansion in computer use in the 1980s can account for 1/3-1/2 of the increase in the rate of return to education.
McGuckin, Streitwieser, and Doms (1998)	US	1988, 1993	Selected 5 (SIC 2-digit) manufacturing industries (6 917 plants from 1988 SMT; 6 122 plants from 1993 SMT)	- Survey of Manufacturing Technology (SMT) - Longitudinal Research Database (LRD)	Regression analysis (labour productivity on the use of advanced technology)	- Plants using advanced technologies exhibit higher productivity, even after controlling size, age, capital intensity, labour skill mix, industry and region. - While the use of advanced technology is positively correlated to improved productivity performance, the data suggest that the dominant explanation for the observed cross-sectional relationship is that good performers are more likely to use advanced technology than poorly performing operations.

Table 2.2 Human capital and productivity: selected studies

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Entorf and Kramarz (1997, 1998)	France	1985-1987	- 35 567 observations of the longitudinal sample where individual workers are followed at most three years (1985-1987) - 15 946 workers for cross-section estimation with detailed information on new technology (NT) use and with the id number of employing firms (1987)	- 1985-1987 French Labour Force Surveys - 1987 complement of the French Labour Force Survey	Regression analysis (wage on NT use, experience with NT, and firm dummies)	- Computer-based new technologies are used by workers that were already better paid than their fellow workers before working on these machines. - These workers seem to become more productive when they get more experienced with these NT.
DiNardo and Pischke (1997)	Germany	1979, 1985-1986, 1991-1992	Employed population aged 16 to 65 (each survey has slightly less than 30 000 respondents)	Qualification and Career Survey conducted by the Federal Institute for Vocational Training (BIBB) and the Institute for Labour Market Research (IAB)	Regression analysis (wage on computer-use dummy and/or dummies for calculator-, telephone-, pen/pencil-use, and for sedentary work)	- Estimated computer wage premium is similar to that found by Krueger (1993) from the US data. - However, the measured wage differentials associated with other "white collar" tools such as pen/pencil are almost as large as those measured for computer use. - The results seem to suggest that computer users possess unobserved skills which might have little to do with computers, or that computers were first introduced in higher paying occupations or jobs.
Kölling (1999)	Germany	1993-1998	4 000+ establishments in western Germany	IAB-Establishment Panel (based on the employment statistics register of the Federal Employment Services)	Regression analysis (share of qualified workers in the firm's total workforce)	- Some evidence for a skill-biased technological change in the long-run and labour hoarding in the short-run - The idea that international trade forces the structural labour demand towards a larger share of highly skilled is not supported.
Barret and O'Connel (1999)	Ireland	1993, 1995	654 respondents from nationally represented random sample of 1 000 enterprises with more than 10 employees (among which 215 responded to a follow-up survey)	- 1993 survey on company training - Follow-up survey on sales, fixed assets, size of workforce as of 1993 and 1995	Regression analysis (changes in labour productivity)	- While general training has a positive effect on productivity growth, no such effect is observed for specific training. - The impact of general training varies positively with the level of capital investment.

Table 2.2 **Human capital and productivity: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Haskel and Heden (1999)	UK	1972-1992 (1986, 1988 reporting plant's computer spending)	All manufacturing industries (each year, around 15 000 plants with no less than 20 employees; in 1986 and 1988, 10 220 and 10 074 plants, making a panel of 6 986 plants)	- Annual Business Inquiry Respondents Database (ARD) - Policy Studies Institute (PSI) data at the industry level	- Decomposition of non-production labour share changes - Regression analysis (changes in wage bill share of non-manual workers)	- Skill upgrading over the period is mostly driven by within-establishment changes in skill composition. - Computerisation reduced demand for manual workers.
Black and Lynch (1997)	US	1987-1993	627 manufacturing establishments obtained from matching the above EQW-NES with LRD	- The Educational Quality of the Workforce National Employer Survey (EQW-NES) - Longitudinal Research Database (LRD)	Regression analysis (labour productivity)	Greater involvement of workers in decision making and the use of performance related pay are seen to generate higher productivity relative to more traditional labour/management relations.
Black and Lynch (2000)	US	1993, 1996	Panel of 760 establishments constructed from two waves of EQW-NES (manufacturing and non-manufacturing)	- Educational Quality of the Workforce National Employer Survey for 1993 (EQW-NES I) - Educational Quality of the Workforce National Employer Survey for 1996 (EQW-NES II)	Regression analysis (labour productivity, wage)	- A positive and significant relationship between the proportion of non-managers using computers and productivity of establishment - Firms that re-engineer their workplaces to incorporate more "high performance practices" experience higher productivity and higher wages. - Profit sharing and/or stock options are associated with increased productivity but also with lower pay for worker (especially technical/clerical/sales workers).
Lynch and Black (1995), Black and Lynch (1996)	US	1993	Private establishments with more than 20 employees drawn from the Bureau of Census Standard Statistical Establishment List (SSEL) file (1 621 plants in manufacturing; 1 324 in non-manufacturing)	The Educational Quality of the Workforce National Employer Survey (EQW-NES)	Regression analysis (probability of providing formal training programs; share of workers trained; and labour productivity)	- Employers who have made large investments in physical capital or who have hired workers with higher average education are more likely to invest in formal training and to train a higher proportion of their workers, especially in the manufacturing sector. - For manufacturing, the greater the proportion of time spent in formal off-the-job training, the higher the productivity.

Table 2.3 **Employment and technology: selected studies**

Authors	Methodology	Level of Aggregation	Indicators of Technical Change	Measures of Labor	Results
<i>A. Complementarity of technology and skill</i>					
Bartel and Lichtenberg (1987)	Estimation of restricted variable cost function for labor	61 manufacturing industries in 1960, 1970, 1980	Proxies for age of the capital stock	Age, education, gender cells	Older technology negatively correlated with percentage of labor cost devoted to high-skill workers
Berman, Bound, and Griliches (1994)	Decomposition of changes in employment share of nonproduction workers, 1979-89	Four-digit SIC, manufacturing	Expenditure on computers, R&D	Nonproduction workers share in total employment and wage bill	Positive correlation between new technology and skills upgrading
Berndt, Morrison, and Rosenblum (1991)	Regressions of labor intensity measures on "high-tech office equipment" capital intensity	Two-digit SIC industry	High-tech office equipment capital stock	Age, education cells for production and nonproduction workers	Positive correlation between technology measure and share of nonproduction workers
Lynch and Osterman (1989)	Labor demand curves for 10 occupational classes for workers	One Firm (Bell telephone company), 1980-85; year-state-occupation cell	Changes in technology of electronic switching equipment	10 occupational classes of workers	Technology shifts demand in favor of technical and professional employees
Machin (1996)	Changes in employment shares of skilled workers regressed on technical change in two samples (industry and establishment)	16 U.K. manufacturing industries, 1982-89; panel of 402 U.K. establishments in 1984 and 1990	R&D expenditure/sales; lagged SPRU innovation counts; introduction of microcomputers	Employment shares of nonmanuals in industry samples; employment shares of six skill groups in plant-level sample	Innovations and R&D positively related to nonmanual share; computers positively related to upgrading only for top skill group
Mishel and Bernstein (1994)	Change in shares of employment of five educational groups regressed against technological proxies	34 industries (manufacturing and nonmanufacturing), 1973-89	Computing and capital equipment per worker; employment share of scientists and engineers	Proportion of workers with different schooling attainment (five groups); also gross and residual wage inequality	Technology proxies are positively related to educational proportion <i>but</i> this effect does not increase in the 1980s
Osterman (1986)	Change in employment in response to computer installations 1972 and 1978; 3SLS	20 manufacturing and nonmanufacturing industries	Total amount of main computer memory in industry	Employment of clerks, nondata entry clerks, managers, and others	Computerization associated with falls in employment of clerks and managers; long-run effects for managers significantly smaller than short-run effects

Note: SIC = Standard Industrial Classification; SPRU = Science Policy Research Unit; 3SLS = Three-Stage Last Squares; the table does not include studies relating technological change to wages or wage bill directly; only selected recent studies have been included; all studies were conducted in U.S. unless otherwise stated.

Source: Van Reenen (1997)

Table 1. Table 2.3 **Employment and technology: selected studies** (continued)

Authors	Methodology	Level of Aggregation	Indicators of Technical Change	Measures of Labor	Results
<i>B. Effect of technology on employment</i>					
Blanchflower, Millward, and Oswald (1991)	Employment growth rate as function of lagged employment (t – 4) and other characteristics of establishment (demand, foreign ownership, union presence, organizational change, financial performance and capacity)	948 British establishments in 1984 with over 24 workers	Whether there had been any major introductions of new microelectronic plant and equipment in the previous 3 years	Total establishment employment	Positive and significant effect of advanced technical change on employment growth
Blanchflower and Burgess (1995)	Change of employment over average of current and lagged employment. Controls include lagged employment (t – 4), age, unionization, demand, industry dummies	831 British establishments in 1990; 888 Australian establishments in 1989	Whether there had been any major introductions of new plant and equipment in the previous 3 years	Total establishment employment	Positive and significant effect in Britain; positive and weakly significant in Australia
Doms, Dunne and Roberts (1994)	Employment growth regressions and survival probits. Controls for age, capital, size and productivity.	U.S. plants-level data from Longitudinal Research Database and Survey of Manufacturing Technology, 1987-91	Dummy variables representing numbers of advanced manufacturing technologies present in workplace	Growth of employment in establishment	Positive effects on employment growth
Entorf and Pohlmeier (1991)	Three equation system (exports, innovation, and employment)	2 276 West German firms in 1984	Survey of innovations (dummy variable)	Total employment in firm	Product innovations correlated with significantly higher employment (and exports)
Machin and Wadhvani (1991)	Employment growth rate as function of lagged employment (t – 4) and other characteristics of establishment (demand, foreign ownership, union presence, organizational change, financial performance and capacity)	721 British establishments in 1984	Whether there had been any major introductions of new microelectronic plant and equipment in the previous 3 years	Total establishment employment	Significant and positive correlation with total employment growth
Nickell and Kong (1989)	Three equation system (production function, pricing, and product demand). Estimated separately across nine manufacturing industries	45 three-digit British manufacturing industries, 1974-85 panel	Labor augmenting technical change estimated indirectly as a residual	Total employment	Labor augmenting technical change associated positively with employment in seven out of nine industries

Note: SIC = Standard Industrial Classification; SPRU = Science Policy Research Unit; 3SLS = Three-Stage Last Squares; the table does not include studies relating technological change to wages or wage bill directly; only selected recent studies have been included; all studies were conducted in U.S. unless otherwise stated.

Source: Van Reenen (1997)

Table 2.4 Other links with productivity: selected studies

Author	Topic	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Blanchflower and Machin (1996)	Competition	Australia and UK	1990	2 061 British workplaces with no less than 25 employees; 2 004 Australian workplaces with no less than 20 employees	- UK: The British 1990 Workplace Industrial Relations Survey (WIRS3) - Australia: The Australian Workplace Industrial Relations Survey (AWIRS)	Regression analysis (ordered probit estimation of relative productivity and productivity growth equations; OLS estimation of wage equations)	The results suggest rather limited support for the competition hypothesis. No significant competition effects on productivity are found in the UK data. In Australia, there is evidence of a positive competition effect but only in manufacturing establishments. Simple data description suggests that establishment faced with more competitors pay lower wages, but other factors (unionisation, worker characteristics, etc.) seem more important as determinants of wages and productivity.
Bottasso and Sembenelli (2001)	Competition	Italy	1977-1993	745 privately-owned manufacturing companies in Italy, with no less than seven consecutive observations over the 1977-1993 period	Data set constructed by CERIS-CNR by merging balance sheet data (by Mediobanca, a large investment bank) with industry level data (by ISTAT, the Italian Central Statistical Office)	Regression analysis (Production function estimations under imperfect competition (<i>à la Hall</i>) for the pre-single market program (SMP) period and its implementation period)	- The EU Single Market Program (SMP: proposed 282 specific measures to remove non-tariff barriers in the EU) appears to have reduced market power of firms operating in industries where non-tariff barriers were perceived to be high. - For these most sensitive firms, their productivity growth rates jumped in the 1985-1987 period, <i>i.e.</i> immediately after the program announcement.
Disney, Haskel and Heden (2000)	Competition	UK	1980-1992	Around 143 000 establishments (119 000 single establishments; 24 000 units belonging to multi-plant enterprises)	ARD (Annual Census of Production Respondents Database)	- Productivity growth decomposition (labour productivity and TFP) - Regression analysis (conditional probability of exit by Cox proportional hazard method) - Regression analysis (survivor productivity growth by market competition measures: industry concentration, import penetration, market share, and rents)	- 'External' restructuring (exit of less efficient plants, entry and growth of more efficient plants) accounts for 50% of labour productivity growth and 90% of TFP growth over the period. - Survival analysis shows that plants with below average productivity are more likely to exit. - Market competition significantly raises both the level and growth of productivity even after controlling for the potential selection bias.

Table 2.4 Other links with productivity: selected studies (continued)

Author	Topic	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Nickell (1996)	Competition	UK	1972-1986	Around 700 UK manufacturing companies	Published accounts from the EXSTAT company database, augmented by a postal survey of a subset of 147 companies	Regression analysis (production function with various competition measures: market share, a survey-based competition measure, and average rents normalised on value-added at the firm level, concentration measures and import penetration at the 3-digit industry level)	<ul style="list-style-type: none"> - Market power (measured by market share) appears to reduce <i>levels of productivity</i>. - Competition (measured either by increased numbers of competitors or by lower levels of rents) is associated with higher <i>productivity growth rates</i>.
Nickell, Nicolitsas and Dryden (1997)	Competition	UK	1982-1994	582 UK manufacturing firms	Published accounts from the EXSTAT and EXTEL company databases; additional information on the number of competitors and ownership for subsets of companies	Regression analysis (explanatory variables include: average rents normalised on value-added (an inverse measure of competition); interest payments normalised on cash flow; dominant shareholder dummies)	<ul style="list-style-type: none"> - Product market competition, financial market pressure and shareholder control are associated with increased productivity growth. - There is some evidence to suggest that the last two factors can substitute for competition. The impact of competition on productivity performance is lower when firms are under financial pressure or when they have a dominant external shareholder.
Oulton (1998)	Competition	UK	1989-1993	About 140 000 companies (of which 87 000 are independent, 53 000 are subsidiaries)	The OneSource database by OneSource Information Services Ltd.	Regression analysis (labour productivity and productivity dispersion)	<ul style="list-style-type: none"> - Productivity dispersion is very wide in any year, but there are significant differences between sectors. About three quarters of the variance of productivity is due to differences between firms in the same industry. - Amongst surviving companies, the rate at which productivity approaches the mean is higher for companies which were initially below the mean. - Manufacturing sectors have significantly lower dispersion than the rest of the economy. One explanation is that manufacturing sectors are more exposed to international competition than service sectors.

Table 2.4 Other links with productivity: selected studies (continued)

Author	Topic	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
McGuckin and Nguyen (1995)	Corporate governance	US	1977, 1982	Food manufacturing industry (SIC 20) (unbalanced panel of 28 407 plants)	Longitudinal Research Database (LRD)	Regression analysis (probability of ownership change)	<ul style="list-style-type: none"> - Ownership change is generally associated with the transfer of plants with above average productivity, but large plants are more likely to be purchased rather than closed, when they are performing poorly. - Transferred plants tend to experience improvement in productivity performance following ownership change.
Griffith (1999)	Export	UK	1980-1992	Motor vehicle industry (5 314 observations on 1 176 establishments over the period 1980-1992; unbalanced panel of 414 establishments with 3 259 observations used for regression)	Annual Business Inquiry Respondents Database (ARD)	Regression analysis (estimating production functions)	<ul style="list-style-type: none"> - Using the estimates of TFP from the static specification, German-owned plants in the motor vehicle and engines (SIC351) industry have around 12% and other foreign-owned have around 18% higher TFP than domestic-owned plants. - The estimates of TFP obtained using the dynamic specification indicate that only US-owned plants have higher TFP levels and this difference is fairly small, at around 6%.
Bernard and Jensen (1999)	Exports	US	1983-1992	All manufacturing industries (unbalanced panel with 50 000 - 60 000 plants each year)	Annual Survey of Manufactures (ASM) from Longitudinal Research Database (LRD)	<ul style="list-style-type: none"> - Regression analysis (TFP/employment/shipment growth on export dummy) - TFP growth decomposition by plant type on export status 	<ul style="list-style-type: none"> - The positive correlation between exporting and productivity levels appears to come from the fact that high productivity plants are more likely to enter foreign markets. - Faster growth of exporting plants, coupled with their higher productivity levels, provides a mechanism for exporting to augment aggregate productivity growth.
Bernard and Wagner (1998)	Exports	Germany (Lower Saxony)	1978-1992	All manufacturing industries (unbalanced panel of 7 624 plants with employees \geq 20)	Annual Survey of Manufacturing Establishments	Regression analysis (probability of entering the export market)	<ul style="list-style-type: none"> - Sunk costs for export entry appear to be substantial in Germany (higher than in the US, lower than in developing countries). - Plant success (as measured by size and productivity) increases the likelihood of exporting.

Table 3. Productivity decomposition and related analysis: selected studies

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Baldwin (1996)	Canada	1973-1990	All manufacturing industries (235 industries at the 4-digit level)	Longitudinal data file of plants in the Canadian Census of Manufactures	Decomposition of labour productivity changes	<ul style="list-style-type: none"> - The productivity growth experienced by the Canadian manufacturing sector in the 1970s was considerably higher than in the 1980s. - The evidence suggests that a restructuring phenomenon has been occurring in the Canadian manufacturing sector, with small less productive plants gaining employment share at the expense of the more productive.
Maliranta (1997)	Finland	1975-1994	All manufacturing industries (plants with 5 or more employees classified into 15 sub-industries)	The Finnish Industrial Statistics	Decomposition of labour productivity and TFP growth	<ul style="list-style-type: none"> - In each year, 2-6% of the labour hours are lost due to the closure of plants, while new plant entry covers 2-5% of total labour hours. - The relative importance of the entry-exit effect in the aggregate productivity growth seems to have increased especially since the early 1980s.
Hahn (2000)	Korea	1990-1998	All plants with 5 or more employees in mining and manufacturing industries	Unpublished data underlying <i>Annual Report on Mining and Manufacturing Survey</i>	Decomposition of TFP growth	Plant entry and exit effects accounted for 45% of aggregate productivity growth during cyclical upturn (1990-1995) and 65% during cyclical downturn (1995-1998).
Bartelsman, Leeuwen, and Nieuwenhuijsen (1995)	Netherlands	1980, 1991	All firms with more than 10 employees (8 859 firms in 1980, 8 388 firms in 1991, among which 4 261 continuers, 4 598 exiters, and 4 127 entrants)	<ul style="list-style-type: none"> - 1980 Survey of Production - 1991 Survey of Production 	Decomposition of labour productivity and employment changes	<ul style="list-style-type: none"> - Net firm turnover contributes a third of the 3% annual average growth of labour productivity. This happens because exiting firms are much less productive than the average firm. - Successful upsizers appear to contribute slightly more to the aggregate productivity growth than the successful downsizers.
Baily, Bartelsman, and Haltiwanger (1996a)	US	1977, 1987	All manufacturing industries (140 051 "continuers" plants + "exiters" + "entrants")	Longitudinal Research Database (LRD)	Decomposition of labour productivity growth by quadrants based on productivity-employment changes	Plants that increased employment as well as productivity ("successful upsizers") contributed to overall productivity growth almost as much as plants that increased productivity at the expense of employment ("successful downsizers").
Baily, Bartelsman, and Haltiwanger (1996b)	US	1972-1988	All manufacturing industries (8 669 plants that were in operation in all years from 1972 to 1988)	Longitudinal Research Database (LRD)	Comparing procyclicality of labour productivity by above four quadrants based on productivity-employment changes	Permanently downsizing plants disproportionately account for procyclical productivity, while plants that are upsizing in the long run exhibit little or no procyclical productivity. Internal increasing returns and labour hoarding appear to play little role in the procyclicality of productivity.

Table 3. **Productivity decomposition and related analysis: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Baily, Hulten, and Campbell (1992)	US	-1963, 1967, 1972, 1977, 1982, 1987 (census) -1972-1988 (annual survey)	23 (SIC 4-digit) manufacturing industries (plant-level data with firm-identification)	Longitudinal Research Database (LRD)* * LRD was constructed by pooling information from the Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM)	- Productivity growth decomposition (TFP-based) - Regression analysis (productivity, exit, and plant growth)	- Plant closure is frequent even within successful and growing industries. - Strong persistence in relative productivity of plants. - Growing output share in high-productivity plants is a major factor in the productivity growth of an industry.
Foster, Haltiwanger, and Krizan (1998)	US	1977, 1982, 1987	All manufacturing industries and a selected service industry (automotive repair shops: SIC 753)	- Census of Manufactures (CM) - NBER Productivity Database - Census of Services	- Productivity growth decomposition (multifactor- and labour-productivity) - Regression analysis (productivity on exit/entry dummies, etc.)	- Reallocation of outputs and inputs from less productive to more productive plants makes a significant contribution to aggregate productivity growth. - The contribution of net entry to aggregate productivity growth is increasing in the horizon over which the changes are measured since longer horizon yields greater differentials from selection and learning effects. - The contribution of reallocation to aggregate productivity growth varies over time (e.g. is cyclically sensitive) and industries, and is sensitive to subtle differences in measurement and decomposition methodologies.

Table 4. **Productivity-related analysis of non-manufacturing sectors: selected studies**

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Bernstein (1999)	Canada	1978-1989	Life insurance industry (12 major firms)	Firm-level data from the Office of the Superintendent of Financial Institution (OSFI)	Estimating TFP growth rates	Over the period from 1979 to 1989, the average annual rate of productivity growth was about 1%.
Diewert and Smith (1994)	Canada	1988:Q2 - 1989:Q4	A large appliance parts distributor in Western Canada (The firm has outlets in seven locations: Vancouver, Victoria, Coquitlam, Edmonton, Calgary, Saskatoon, and Winnipeg)	The firm's data on inventory holding, sales, and purchases	Deriving a consistent accounting framework for the treatment of inventories in measuring the productivity of a distribution firm (distinguishing 5 classes of net outputs and 5 classes of inputs)	<ul style="list-style-type: none"> - The average TFP growth rate measured by refined accounting framework was 9.4% per quarter. - Such productivity gains are made possible by the computer revolution which allows a firm to track accurately its purchases and sales of inventory items and to use the latest computer software to minimise inventory holding costs.
Hamandi (2000)	Canada	1994-1996	Engineering services (SIC 7752) sector	1997 Survey of Innovation	Tabulations of survey results by firm size, innovation type, etc.	Large engineering services firms are very innovative, with three out of four firms introducing innovations from 1994 to 1996. Firms perceive that market uncertainties and difficulties in obtaining capital are their most significant barriers to innovation.
Hamdani (1998)	Canada	1991-1994	Services sector (excluding government, education, and health services) and goods sector	Longitudinal Employment Analysis Program (LEAP) database	Tabulation of firm's entry/exit rates by sub-industries (measuring volatility as the sum of entry and exit rates)	Service sector is more volatile than the goods-producing industries. Many firms enter business service and communication industries but stiff competition forces many to close down or merge with other firms. On balance, however, these industries have recorded the largest increases in the number of firms since 1983.

Table 4. Productivity-related analysis of non-manufacturing sectors: selected studies (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Heisz and Côté (1999)	Canada	1976-1996	Services sector and goods sector	- Labour Force Survey (LFS): 1976-1996 - Longitudinal Worker File* (LWF): 1978-1995 * A large longitudinal sample of some 1.8 million workers in insurable employment	Tabulations by industry (average complete duration of a new job; hiring rates, layoff rates, quit rates)	- The shift towards services employment (particularly, consumer services) has not had a noticeable impact on aggregate job stability in Canada. - Job stability in the services industries tends to vary less with business cycles than that in manufacturing.
Kremp and Mairesse (1992)	France	1984-1987	Balanced and cleaned sample of 2 289 firms in selected 9 service industries (Restaurants; Hotels; Engineering; Computer programming; Computer processing; Legal services; Accounting; Personnel supply; Building cleaning)	Annual firm surveys (<i>enquêtes annuelles d'entreprises</i>) on services (detailed survey on all firms with no less than 20 employees + simpler survey on a representative sample of smaller firms)	Tabulations of productivity (value added per person) and profitability (operating income to sales ratio): level, growth, and dispersion.	- The differences across industries in average productivity and profitability are usually small when compared to the range of individual differences within industries. - The industry effects largely predominate in explaining the dispersion of productivity and profitability levels, while the dispersion in the productivity growth rates and profitability changes is only weakly related to the industry breakdown.
Licht and Moch (1999)	Germany	1993-1995	All service sector (about 2 800 firms with no less than 5 employees)	- Mannheim Innovation Panel for the Service Sector (MIP-S) (based on a mail survey to the firms in the records of CREDITREFORM, Germany's largest credit-rating agency) - German Information Technology Survey	Regression analysis (qualitative assessments of innovation impacts; labour productivity)	Information technology (IT) has strong impacts on the quality aspect of service innovations. As IT-investment seems to often be associated with quality aspects of service innovations, there is the danger that labour productivity or total factor productivity will not adequately reflect the true impact of IT.

Table 4. Productivity-related analysis of non-manufacturing sectors: selected studies (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Giorgi and Gismondi (1999)	Italy	1995	Retail trade (NACE 52) industry (6 100 firms)	Enterprises' Account Survey by the National Statistical Institute of Italy (ISTAT)	Regression analysis (Labour productivity* on firm characteristics such as employment size class, geographic area, investment class, etc.) * Measured as turnover per employee.	<ul style="list-style-type: none"> - Factors such as class of investments and geographic location are not so relevant in order to detect difference in productivity levels. - Employment size class has a stronger influence on productivity than the sector of activity by 3-digit NACE.
Santarelli (1998)	Italy	Jan. 1989 – Dec. 1994	Tourist (hotels, restaurants, and catering firms) industry (starting with 11 660 new firms with at least one paid employee in 1989 and tracking them over subsequent years)	National Institute for Social Security (INPS)	Regression analysis (probability of survival on start-up size for new firms by regions)	<ul style="list-style-type: none"> - Survival patterns differ significantly across different regions. - The hazard function (showing the risk of failure at each point in time conditional on survival up to the previous time period) has a bell shape with a peak at the second year of the activity. - There exists a positive and significant association between start-up size and the likelihood of survival for the majority of regions and for the country as a whole.
Baltagi, Griffin, and Rich (1995)	US	1971-1986	24 airlines (unbalanced panel of 293 observations)	N/A	Regression analysis (estimating a translog variable cost function)	Despite the slowing of productivity growth in the 1980s, deregulation does appear to have stimulated technical change due to more efficient route structures.
Berger and Humphrey (1992)	US	1980, 1984, 1988	Banking industry (about 14 000 banks)	FDIC Reports on Condition and Income	Estimating multiple-equation thick-frontier cost functions	<ul style="list-style-type: none"> - Most of the dispersion in bank costs appears to represent inefficiencies, rather than market factors such as differences in input prices, scale of operations, or product mix. - Except for the very largest banks, the inefficiencies are mainly operational in nature, involving overuse of physical labour and capital inputs, rather than financial, involving excessive interest costs. - Operating cost dispersion and inefficiency rose substantially over the period, particularly from 1984-1988, suggesting a less than complete adjustment to the new, less regulated equilibrium.

Table 4. Productivity-related analysis of non-manufacturing sectors: selected studies (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Fixler and Zieschang (1992)	US	1984-1988	Banking industry (400+ banks with international operations or assets over US\$300 million from 1984:Q1 to 1988:Q4)	Federal Deposit Insurance Corporation (FDIC) Reports on Condition and Income (containing quarterly balance sheet and income statement call reports)	Estimating price and quantity indexes for the banking sector	<ul style="list-style-type: none"> - Estimated output index rose by 8.8% per year during 1984-1988, much faster than parallel estimates by the Bureau of Labor Statistics (3.6%) and by the Bureau of Economic Analysis (0.7%). - The quantity index is shown to be stable over the variations in the opportunity cost rate given by the rule-of-thumb estimates.
Fixler and Zieschang (1993)	US	1984-1988	Banking industry (about 2 000 banks in each of the years 1984-1988; a cohort of 160 banks that merged in 1986)	FDIC Reports on Condition and Income (containing all banks involved in mergers approved by the Office of Comptroller of the Currency in the year 1986)	Tabulations of relative productivity based on a superlative index number approach	<ul style="list-style-type: none"> - Acquiring banks achieved no gains in efficiency from merger, but acquiring banks were consistently more productive than the sample as a whole. - By implication, if mergers can be generally characterised as the acquisition by a relatively more productive bank of a relatively less productive bank, then industry performance should improve as a result of these mergers.
Gort and Sung (1999)	US	1952-1991	Telephone industry (AT&T Long Lines and 8 regional companies)	<ul style="list-style-type: none"> - Statistics of Communications Common Carriers by the Federal Communications Commission (FCC) - Form M reports to FCC 	Regression analysis (TFP regressions and cost function regressions. Output index constructed by deflating revenues by price indices for local service, toll service, and a miscellaneous category)	Both the estimation of TFP growth and the analysis of shifts in cost functions show a markedly faster change in efficiency in the effectively competitive market than for the local monopolies.
Kim, E. H. and Singal (1993)	US	1985-1988	14 airline mergers that were initiated during the period 1985-1988 (21 351 routes affected)	Ticket Dollar Value Origin and Destination data bank by the Department of Transportation	Regression analysis (relative fare changes)	<ul style="list-style-type: none"> - Routes affected by mergers show significant increases in airfares relative to the control group. - These price increases are positively correlated with changes in concentration and do not appear to be the result of an improvement in quality. - The fare changes are also positively related to the distance of routes, suggesting that airlines exploit greater market power on longer routes for which substitution by other mode of transportation is less likely. - Mergers may lead to more efficient operations, but on the whole, the impact of efficiency gains on airfare is more than offset by exercise of increased market power.

Table 4. **Productivity-related analysis of non-manufacturing sectors: selected studies** (continued)

Author	Country	Sample Period	Sample Coverage	Data Sources	Main Methods	Major Findings
Lichtenberg and M. Kim (1989)	US	1970-1984	25 airlines for 1970-1984 and 10 start-up airlines for 1982-1984 (272 out of 420 annual observations on these airlines)	Database developed by Caves, Christensen, Tretheway and Windle (which was based on the Civil Aeronautics Board(CAB)'s Form 41 Report filed annually by each airline company)	Regression analysis (Estimating effects of mergers on selected variables such as unit cost and TFP. Output and some inputs are represented as multilateral indices of a number of components.)	<ul style="list-style-type: none"> - The average annual rate of unit cost growth of carriers undergoing merger was 1.1% lower, during the 5-year period centred on the merger, than that of carriers not involved in merger. - Part of the cost reduction is attributable to merger-related declines in the prices of inputs, particularly labour, but about 2/3 of it is due to increased total factor productivity. One source of the productivity improvement is an increase in capacity utilisation (load factor).
Rose (1987)	US	1973-1985	Full-time truck drivers employed in the for-hire trucking industry (2 172 observations over the period)	Current Population Surveys (CPS) by the Bureau of Census	Regression analysis (wage on union status dummy, worker characteristics, and regional dummies)	Union premiums over non-union wages in the trucking industry declined of roughly 40%, beginning in 1979, which coincides with the timing of deregulation in the trucking industry.

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