DANMARKS NATIONALBANK

29 SEPTEMBER 2017 — No.18

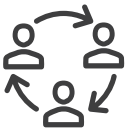
Diffusion of new knowledge benefits firms' productivity

- Productivity growth in the Danish economy since 1995 has been lower than previously. This reflects weak productivity growth in services, while manufacturing has maintained its strong momentum. The decline in productivity growth is an international trend.
- Growth in aggregate productivity is broad-based in Denmark. It is not only driven by a small group of high-productivity firms. Over the last 15 years, productivity has increased by 77 and 56 per cent, respectively, in high-productivity and middle-productivity industrial firms, indicating diffusion of knowledge and technological advances.
- Productivity levels vary considerably across firms within the same industry. Large and old firms generally have higher productivity than small and new firms. Similarly, exporters have higher productivity.

Small difference

in productivity growth between high-productivity and middle-productivity firms

Read more



High job turnover

and a favourable innovation climate contribute to knowledge diffusion

Read more

Large firms,

old firms and exporters generally have higher productivity

Read more

Weak productivity growth since 1995

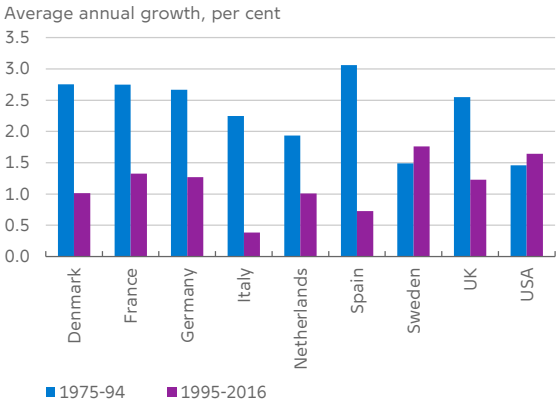
Since 1995, annual productivity growth in the Danish economy has averaged 1.0 per cent calculated as real gross domestic product, GDP, per hour worked, cf. Chart 1. This is around one-third of the annual growth rate of 2.8 per cent in 1975-94. Productivity growth has slowed down similarly in several other countries since the mid-1990s.[1] This has attracted considerable attention, since productivity growth is a key precondition for continued growth in prosperity, cf. Box 1.

Weaker productivity growth driven by services

Measured as real gross value added, GVA, per hour worked, productivity growth has varied considerably across industries, cf. Chart 2. Since 1995, annual productivity growth has been around 3 per cent in manufacturing, relative to just over 4 per cent in the preceding period. This suggests that manufacturing has maintained its strong momentum despite the fact that low investment in recent years has contributed to weak growth in the average capital stock per person employed. In contrast, the development has been weaker in a number of services. In trade, which is employment intensive, annual productivity growth has been only half as strong after 1995 as in the period up to 1994. According to Statistics Denmark, the level of productivity in business services is actually lower in 2016 than in 1995.[2]

Weaker productivity growth in services to a certain extent reflects different production processes relative to manufacturing. While production in manufacturing is relatively capital-intensive, many services apply technology only to a more modest extent. Consequently, the potential gains from technological innovation are smaller in services. Nevertheless, there

Productivity growth in selected countries Chart 1



Note: The bars denote average annual growth in GDP per hour worked. GDP is measured in dollars, adjusted for purchasing power parity, 2010-prices. Data for the USA covers 1995-2015.
Source: OECD.

Economic prosperity depends on productivity Box 1

Productivity is value added in the production of goods or services relative to the amount of input. Production input is typically made up of machines and buildings (i.e. the capital stock) on the one hand and labour on the other. The amount of labour employed in Danish firms depends to a large extent on demographics. Viewed in isolation, this will make a negative contribution to the supply of labour in the coming years in step with the increasing share of the population reaching retirement age.

Employment also depends on factors that can be influenced through regulation and legislation. For example, the adopted increases of the retirement age will contribute to countering the effect of a higher number of elderly people. Previously, reforms of e.g. the cash benefit system have also contributed to enhancing employment among people of working age. Although there is still room for more reforms to increase the supply of labour, there are limits to how much a population of a given size can work overall.

A continued increase in productivity is therefore decisive for future progress in the standard of living. A higher standard of living can generate both more opportunities of consumption and more leisure time.

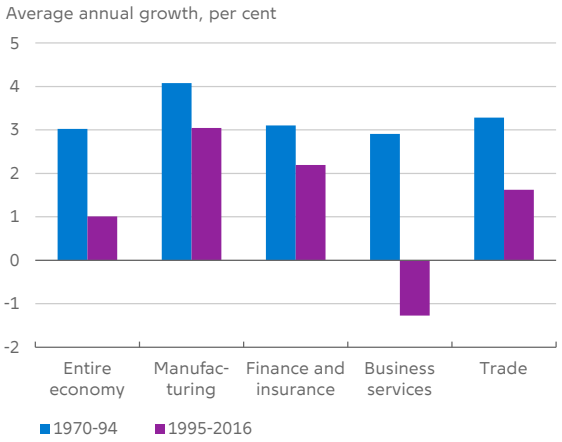
1 For international comparisons, GDP rather than GVA is used for calculation of productivity. One reason is the availability of comparable cross-country figures for GDP adjusted for purchasing power parity.

2 Productivity is more difficult to calculate in services than in manufacturing. This reflects that it is difficult to measure improvements in the quality of services provided by e.g. lawyers or hairdressers. Failure to take quality improvements sufficiently into account will lead to underestimation of productivity growth. That is why the size of the decline in productivity growth in services is uncertain. However, the pattern is so clear that there is hardly any doubt that growth has declined over time.

are many examples of how new technology has contributed to boosting productivity in services. A case in point is the streamlining of many work routines as a result of new information and communication technology. Another reason why productivity growth has been weaker in services may be that this part of the economy is less exposed to international competition, or that regulation is stricter.[3]

A key driver of the weak productivity growth in the Danish economy as a whole is thus the slowdown in growth in the individual industries – mainly services – since 1995. In addition, labour has tended to shift from manufacturing towards services where the level of productivity is lower, cf. Jensen and Jørgensen (2016). Moreover, declining production of North Sea oil in recent years has contributed to reducing productivity growth in the economy as a whole, reflecting the modest labour share in raw materials extraction, which implies very high labour productivity.

Productivity growth has declined – especially in services Chart 2



Note: The bars denote average annual growth in real GVA per hour worked.
Source: Statistics Denmark and own calculations.

Diffusion of new knowledge and technology is essential

In the long term, productivity growth depends primarily on new technology and knowledge and on firms embracing them. New technology paves the way for the introduction of new, improved products and processes and for more efficient production of existing products. This gives rise to the hypothesis that the weakening of productivity growth globally is attributable to a slowdown in technological advances, or that new technologies are less cutting edge than previously, cf. Gordon (2016). Conversely, Brynjolfsson and McAfee (2014) argue that we are facing a period of strong growth driven by new technologies, e.g. information and communication technologies.

The extent of diffusion of new knowledge across firms plays an important role. New knowledge is often embraced first by a few firms, e.g. those with large R&D departments. However, there are also examples of how new firms have evolved and grown because an entrepreneur had a bright idea which was translated into new products or services. Against this background, new technology and knowledge can generate high productivity in individual firms.

In order to achieve a substantial effect on aggregate productivity in the economy, it is essential that knowledge diffuses to other firms, or that production resources are allocated to the most productive firms. In the absence of knowledge diffusion, the most productive firms that develop and use new technology, will increasingly outperform other firms in terms of productivity. This means that large and persistent differences in productivity between firms in the same industry could indicate lack of diffusion of new knowledge across firms.

The OECD points out that productivity growth (in the private sector as a whole) is primarily driven by the most productive firms globally – i.e. the productivity frontier, cf. Andrews et al. (2016). The 5 per cent most productive industrial firms in 2013 were almost

3 See also Andersen and Spange (2012) for a discussion of the determinants of productivity growth in Denmark.

30 per cent more productive on average than the 5 per cent most productive industrial firms in 2001. In contrast, average productivity among the remaining industrial firms was at around the same level as in 2001. This pattern is even more pronounced in services.

The study also points out that productivity growth overall has been weakest in the countries with the greatest divergence among firms between the best and the rest. The OECD thus finds that the diffusion of knowledge to less efficient firms is insufficient. However, frequent changes in the composition of the groups of high-productivity (frontier) firms and low-productivity (laggard) firms cannot be ruled out. A start-up, for instance, may have relatively low productivity for several years and then move on to the group of frontier firms. This reflects dynamics.

An ECB study very much supports the OECD's conclusions, especially regarding services in the euro area, cf. ECB (2017). The ECB lists three explanations for the lack of knowledge diffusion: 1. the increasing importance of tacit knowledge which is difficult to share, 2. a slowdown in laggard firms' investment in intangibles, and 3. a decrease in business dynamism, meaning an ongoing shift of production resources from less productive to more productive firms.

The studies by the OECD and the ECB are based on data for several countries. The countries diverge in several ways in relation to business conditions for the firms. This could be in relation to the regulation of the various industries. The OECD finds that the productivity divergence between frontier and laggard firms is strongest in industries subject to extensive product market regulation. Labour market conditions may also affect the diffusion of new knowledge across firms. In some countries, for example, employees move more frequently between firms, transferring knowledge.

Broad-based productivity growth in Danish firms

Among Danish firms, there are no indications that new knowledge only benefits a small group of firms. Based on firm-level data from Statistics Denmark, productivity is calculated for the most productive firms ("top firms") and firms in the middle group ("median firms") in a number of industries. Due to data availability, productivity in the rest of the analysis is calculated as real GVA per full-time employee. The data is described in Box 2.

A representative top firm is defined as the 95th percentile in a given industry in a given year, calculated on the basis of labour productivity. This means that the top firms are not necessarily the same every year. The top firm is more productive than 95 per cent of the firms in the same industry, while 5 per cent of the firms in the industry are more productive. The median firm is more productive than half of the firms in the same industry, while the other half of the firms are more productive.

Description of the firm-level data applied Box 2

The analysis is based on firm-specific accounts statistics from the data underlying Statistics Denmark's Firm Accounts Database covering all private non-primary and non-financial firms in the period 2000-15. Firms are only included in the analysis if their accounts data is neither fully nor partially imputed by Statistics Denmark.

Agriculture, fishing, energy and water supply, ports, etc., railway and bus transport, credit institutions, insurance and pension, social housing organisations, public administration, etc. are not included in the data. Industries with less than 20 firms in at least one of the years 2000-15 are also excluded in order to provide for calculation of the relevant percentiles of the productivity distribution. Also excluded are some particularly capital-intensive service industries where the calculated labour productivity is not regarded as representative of the other services. The analysis focuses on manufacturing and services.

As in Danish Productivity Commission (2013a), firms with negative value added in the given year, the preceding year or the year after are excluded. Firms with non-plausible accounts data are also excluded, e.g. firms with non-positive turnover and assets, just as non-active firms with less than 0.5 per cent full-time employees are excluded. The final sample includes around 1,900 industrial firms and 4,900 service firms on average per year.

Productivity is calculated as labour productivity, i.e. value added per full-time employee. Productivity growth is calculated as changes in real value added per full-time employee, where value added has been adjusted for industry-specific price developments by means of deflators from the national accounts at 69 industry level.

On the basis of the industry-specific results, top and median firms are defined in manufacturing and services, respectively. The industry-specific top and median firms are weighted together with the industries' shares of total GVA for manufacturing and services, respectively.

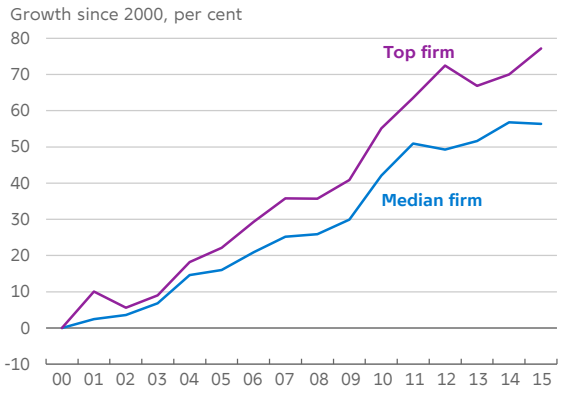
Growth in the median group too

In manufacturing, the representative top firm in 2015 was around 77 per cent more productive than the representative top firm in 2000, cf. Chart 3. For the median firm, productivity rose by 56 per cent in the same period. This is significantly different from the OECD study, which found that productivity for the broad section of firms in the OECD countries has been almost flat for many years.[4] This may indicate that the substantial productivity growth in manufacturing in Denmark reflects, inter alia, diffusion of new knowledge and technology across firms.

In services, the development of productivity is considerably weaker. While the top firm is 16 per cent more productive in 2015 than in 2000, productivity for the median firm has risen by 9 per cent, cf. Chart 4. Thus, the OECD's conclusion that the most productive service firms have become markedly more productive, while productivity has stagnated for other firms, is not reflected in the Danish data.

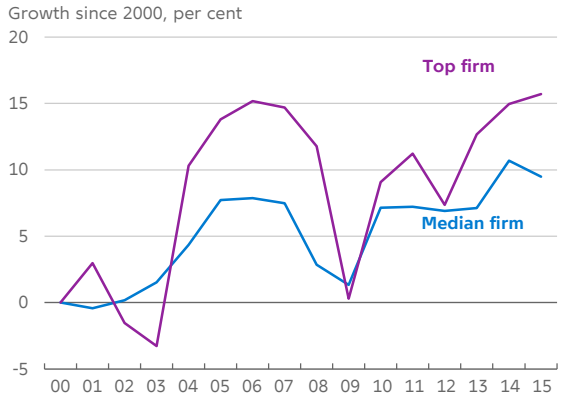
The productivity measure fluctuates considerably year-on-year. Some of the fluctuations reflect cyclical factors. For example, productivity slowed down in connection with the economic downturn in 2008. It may be difficult to adjust staff numbers fast enough in the event of a sudden drop in demand. Moreover, some firms will retain staff during a downturn in order to be ready to expand production quickly when demand increases again. The result is weaker labour productivity. Some of the year-on-year fluctuations also reflect that the firms included in the analysis are not the same in all of the years. Against this backdrop, it is important to

Productivity growth in manufacturing Chart 3



Note: A top firm is more productive than 95 per cent of the firms within its industry and less productive than the remaining 5 per cent. A median firm is more productive than 50 per cent of the firms within its industry and less productive than the remaining 50 per cent. The individual industries have been weighted together with their shares of average value added in the period 2000-15 according to the national accounts.
Source: Statistics Denmark and own calculations.

Productivity growth in services Chart 4



Note: See the note to Chart 3.
Source: Statistics Denmark and own calculations.

4 This method is slightly different from that used in the OECD study where the top is defined as the average productivity of the 5 per cent frontier firms in each industry each year, which is compared with average productivity among laggard firms. However, the analysis results are not dependent on this difference in methodology, as the OECD's methodology produces similar results. The marked increase for the representative top firm as well as the representative median firm may partly reflect a decrease in the number of industrial firms in the sample during the period 2000-15.

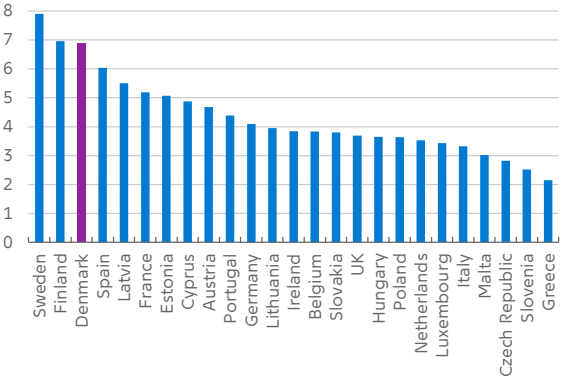
focus primarily on tendencies rather than developments in individual years.

Total productivity increases for the top and median firms depend on the time period, which is limited to the post-2000 years in this analysis. This calls for caution in interpreting the analysis. However, a very clear result is that growth in productivity overall is not only driven by a small group of frontier firms.

Productivity growth, calculated on the basis of register data, diverges from the development in labour productivity calculated in Statistics Denmark's national accounts by industry. This reflects, inter alia, that the sample of firms in the analysis is not completely representative. Small firms are underrepresented in the data set, just as industries with few firms have been excluded. However, the conclusion that the top firms are not decisively outperforming the rest is not assessed to be a consequence of the sample composition.

High job turnover in Denmark Chart 5

Newly hired, in per cent of total employment



Note: Average of quarterly observations over the period 2008-16. Newly hired are defined as employees hired within the last three months.
Source: Eurostat and own calculations.

Several factors ensure knowledge diffusion

There are several possible reasons why the broad section of firms in Denmark have not lagged behind the frontier firms to the same degree. When employees move from job to job, diffusion of knowledge takes place. Job turnover is high in Denmark compared with most other countries, cf. Chart 5.[5] This could contribute to knowledge diffusion within and between industries.

The interaction between public and private research and innovation is another important channel for the diffusion of knowledge. For example, innovation comprises new or improved products, smoother work routines, better organisation and more efficient marketing.[6] Accounting for around 58 per cent of private investment in research and development, manufacturing plays an important role in the development of new knowledge in Denmark, cf. Danish government (2017).

Denmark is the OECD country where public research as a percentage of GDP is highest. In 2015, public research accounted for 1.1. per cent of GDP, cf. Ministry of Higher Education and Science (2017). Cassiman et al. (2008) find, on the basis of a study of Belgian firms, that innovation in private sector firms (patents, etc.) based on public research entails more pronounced knowledge diffusion than other types of innovation.

The European Innovation Scoreboard, EIS, scores Denmark high among the EU member states in terms of innovation, surpassed only by Sweden.[7] The EIS conducts an annual assessment of the EU member states' innovation systems on the basis of framework conditions, investment in research and innovation and firms' innovation activities and their impact. Globally, however, the EU is less innovative than e.g. the USA and Japan.

Regulatory barriers could be an impediment to knowledge diffusion across firms. According to the World Bank (2017), Denmark is among the countries where it is easiest to establish and operate a firm, measured on the basis of ten key business activities, including start-up, building permits and access to credit. Moreover, the effort to create "clusters" of firms in the same industry may have contributed to diffusion of new technology and knowledge, cf. e.g. Ministry of Higher Education and Science (2016).

5 See also Kristoffersen (2016).

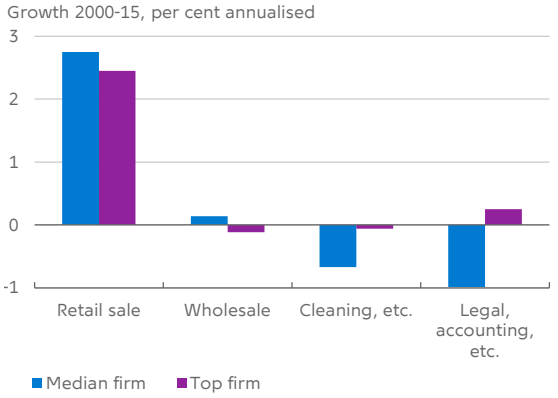
6 See Danish Productivity Commission (2013b).

7 See European Commission (2017).

Services composed of many sub-industries
There are considerable differences between the various services. While some firms supply highly specialised services using highly educated labour (e.g. lawyers and consultant engineers), others supply more operational services (e.g. cleaning and retail sale). An analysis of productivity development in services as a whole may thus mask important factors.

That is why four of the largest service sub-industries are examined here. Trade is among the service industries with declining growth since the mid-1990s, cf. Chart 2. However, this decline does not reflect that a large group of firms have been decoupled from the frontier. In wholesale, annual productivity growth has been close to zero for both median firms and the representative top firm, cf. Chart 6. In retail sale, where aggregate productivity growth has been somewhat higher, there are no indications either of frontier firms outperforming the rest. Especially the results for retail sale should be interpreted with the caveat that small firms are underrepresented in the sample.

Productivity growth in selected service industries Chart 6



Note: A top firm is more productive than 95 per cent of the firms within its industry and less productive than the remaining 5 per cent. A median firm is more productive than 50 per cent of the firms within its industry and less productive than the remaining 50 per cent.
Source: Statistics Denmark and own calculations.

According to Statistics Denmark, productivity growth in business services has been negative for several years, resulting in lower productivity today than in 1995, cf. Chart 2. This industry comprises a number of very different sub-industries. For instance, in cleaning, etc., both the median firm and the representative top firm have lower productivity in 2015 than in 2000, cf. Chart 6. In the sub-industry legal, accounting, etc., on the other hand, the representative top firm has seen slightly positive productivity development over the total period, while the median firm has lagged behind.

Substantial variation in productivity across firms

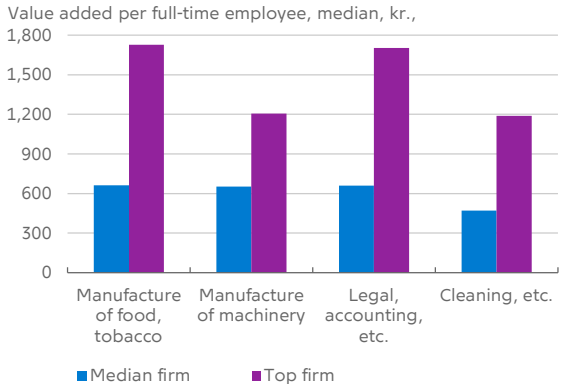
Productivity levels vary considerably across firms. The variation can partly be explained by differences in production structures between industries. For example, the industries where production is based on a large capital stock will typically have relatively high value added per person employed. The same applies to industries with highly specialised labour compared with industries where the general level of qualifications is lower. High value added per person employed in selected industries may, however, also be attributed to weak competition, enabling firms to earn high profit margins.

Productivity levels also vary considerably across firms within the same industry. In manufacture of machinery, value added per person employed in 2015 was thus kr. 1.2 million in the representative top firm and kr. 0.6 million in the median firm, cf. Chart 7. For legal, accounting etc., it was kr. 1.7 million in the representative top firm and kr. 0.6 million in the median firm.

The large productivity divergence within industries reflects that there is great potential for increasing total productivity if the top firms' knowledge and work routines can be transferred to their competitors. Or if the frontier firms are able to increase their market shares to the detriment of the laggard firms, outcompeting and closing the latter. Indeed, the survival rate is higher for frontier than for laggard firms in both manufacturing and services, cf. Chart 8. The survival rate is calculated as the share of firms which were active in 2000 and are still active in a given year.

Despite the differences in survival rates, around 40 per cent of the firms that were low-productivity firms in 2000 were still active in 2015. This may reflect their ability to increase productivity in the interim period.

Substantial differences in value added within industries Chart 7



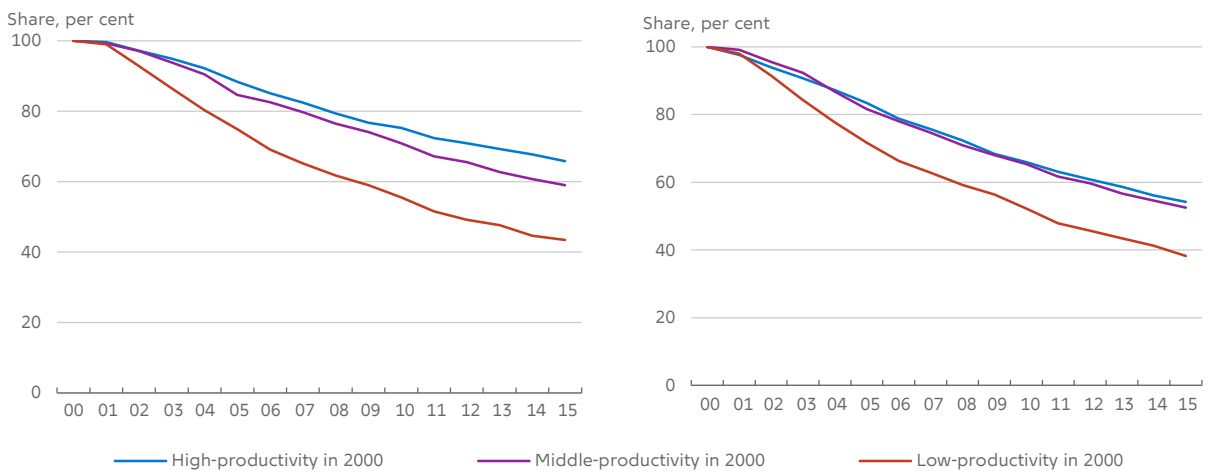
Note: See note to Chart 6. Data for 2015.
Source: Statistics Denmark and own calculations.

It could also indicate a lack of competition, enabling firms to generate profits despite low productivity. However, the services provided by the firms vary substantially even within the industries. For example, some legal services are highly specialised and directed at large firms, while others are of a more general nature directed at households. This means that various law firms target different markets with different prices. The survival of some firms with notably lower value added than other firms in the same industry thus also reflects the different services they provide.

Large and exporting firms generally have higher productivity

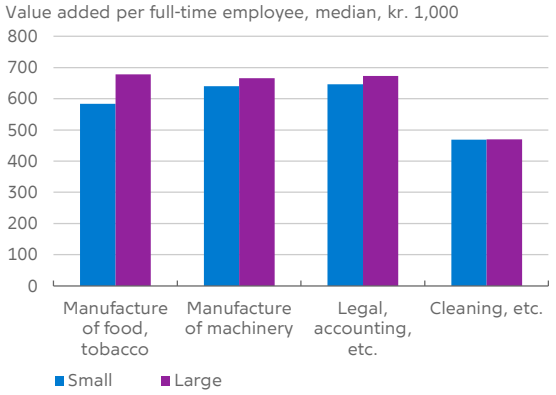
Certain cross-industry characteristics seem to be related to firm productivity. In general, large firms, for instance, tend to be more productive than small firms, cf. Chart 9. This may reflect the importance of economies of scale in many industries, e.g. that the employees of a large consultancy firm have greater opportunities to specialise. Moreover, large indus-

Surviving firms Chart 8



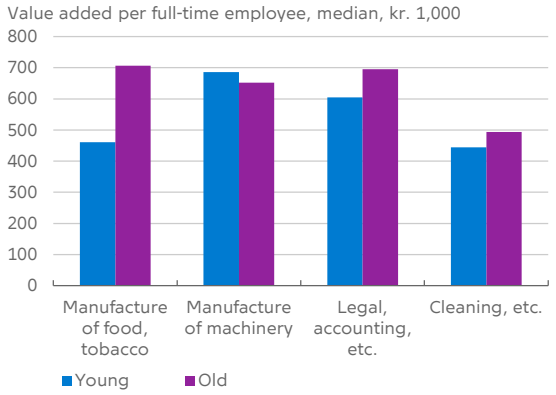
Note.: The charts show the shares of surviving firms by productivity level in 2000. High-productivity firms' productivity in 2000 was higher than the 75th percentile within their industry, middle-productivity firms' productivity was between the 25th and 75th percentiles, while low-productivity firms' productivity was lower than the 25th percentile. Surviving firms are firms with unchanged CVR numbers relative to 2000. Non-surviving firms cover both discontinued firms and firms that have been acquired or have changed their CVR numbers for any other reasons.
Source: Statistics Denmark and own calculations.

Large firms generally have higher productivity than small firms Chart 9



Note: Small firms have up to 50 full-time employees, while the rest are classified as large firms. Data for 2015.
Source: Statistics Denmark and own calculations.

Old firms generally have higher productivity than young firms Chart 10



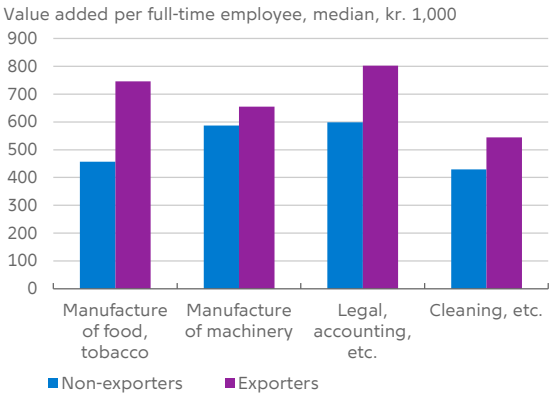
Note: Young firms are less than 10 years old, while the rest are classified as old firms. Data for 2015.
Source: Statistics Denmark and own calculations.

trial firms often have more advanced production facilities than smaller firms.

Old firms also tend to have higher productivity than newly established firms, cf. Chart 10, reflecting to a certain extent that old firms also generally tend to be larger than younger firms. Thus, 23 per cent of the young firms in the analysis are large firms, while 42 per cent of the old firms are large firms. Old firms may also have more well-established production patterns and a better network among suppliers and customers than new ones.

Firms that are exporters to a high or low degree are more productive on average than non-exporters, cf. Chart 11. In manufacture of food and tobacco, median productivity was around 63 per cent higher in 2015 for exporters than for non-exporters. This may reflect that only the most productive firms are able to succeed in export market competition. But it may also reflect that exporting as such has a positive impact on productivity. For example, it enables firms to grow, harvesting the advantages of growth. Furthermore, the interaction with foreign firms as a result of exports also gives access to new knowledge that may strengthen productivity.

Exporters generally have higher productivity Chart 11



Note: Data for 2015.
Source: Statistics Denmark and own calculations.

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ABOUT ANALYSIS

As a consequence of Danmarks Nationalbank's role in society we conduct analyses of economic and financial conditions.

Analyses are published continuously and include e.g. assessments of the current cyclical position and the financial stability.

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This edition closed for contributions on 25 September 2017

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