Can a Rise of Intangible Capital Explain an Increase in Markups?*

PRELIMINARY - COMMENTS WELCOME

Maria Sandström†

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Abstract

This paper contributes to the current discussion on the consequences of a rise in intangible capital and the reasons for an increase in markups observed in several countries. Using a heterogenous-firm model, I show how the uncertainty and scalability of intangible capital imply that firms that succeed in their intangible capital investment can charge high markups relative to other firms. Sweden is one of the most intangibles-intensive economies in the world and I use data on all Swedish firms to study the empirical relationship between intangible capital and markups. I find that markups are positively related to intangible capital at the firm and industry level. However, aggregate markups in Sweden have been low and stable over the past two decades. This provides evidence against the rise of intangible capital as the sole explanatory factor behind the rise in markups observed in other countries in the same time period.

Keywords: Intangible capital, Markups, Market Power.
JEL: E2, D2, L1, L2

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†Institute for International Economics, Stockholm University. E-mail: maria.sandstrom@iies.su.se

1 Introduction

Can a rise of intangible capital explain an increase in markups? In particular for the United States, there is evidence of a substantial increase in firm markups over marginal costs between the 1980s and the present day (De Loecker et al., 2020). De Loecker and Eeckhout (2018) find similar increases in other countries. In parallel, there is evidence of a rise of intangible capital. According to official statistics, investments in intangible capital in the form of R&D, software, and artistic originals amount to about one-third of business investments in several industrialized countries. Including a broader set of intangibles, Corrado et al. (2009) estimate this investment share to be as high as 50 percent.

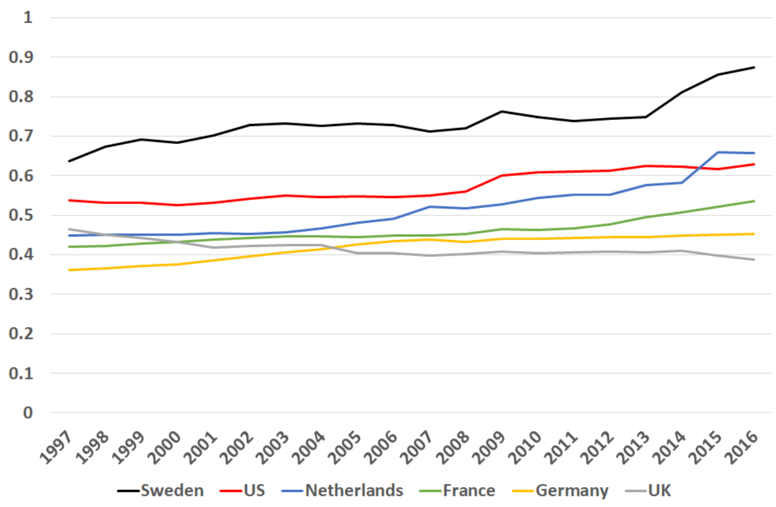
This paper contributes to the current discussion on the consequences of a rise in intangible capital and the reasons for an increase in markups observed in several countries. First, I use a heterogenous firm model to study under what conditions the uncertainty and scalability properties of intangible capital can lead to higher markups. Second, I study the empirical relationship between markups and intangible capital. In particular, I am asking; 1) Is an increase in intangible capital at firm and industry level associated with an increase in markups? 2) What are the aggregate markup trends in an intangibles-intensive economy? It is interesting to study these questions in data from Sweden which is one of the most intangibles-intensive economies in the world. Figure 1 shows that Sweden has a higher intangible capital-intensity than the United States and several large European countries.[1]

I model a rise of intangible capital as a higher level of fixed costs and a higher uncertainty in terms of firm marginal costs. Firms that succeed in their intangible capital investment can charge high markups relative to other firms. The average industry markup generally depends on both the level of the fixed cost and the distribution of the marginal costs of production. When firm marginal costs are distributed inverse Pareto, the model predicts that industries in which intangible capital is more important will be characterized by; i) a higher fixed cost of intangible capital relative to the variable cost (a higher intangible capital-intensity) ii) higher average industry markups.

I test the correlation between intangible capital-intensity and markups using data on firms and industries in Sweden for the period 1997 to 2016. Firm markups are estimated using the production approach proposed by De Loecker and Warzynski (2012) building on work by Hall (1988). Importantly, the registry data on firms cover the universe of

[1]Sweden is the country of origin of many new software-intensive service providers and as well as the base of older R&D-intensive manufacturing firms such as Spotify, Skype, Mojang (Minecraft), and King (Candy Crush), such as Ericsson, Volvo, Scania and AtlasCopco.

Figure 1: Intangible capital-intensity (IC/wL)



Notes: IC/wL refers to the intangible capital stock relative to the cost of labor. Data from the EU KLEMS including the intangibles supplement.

all non-financial firms in Sweden. This is an important contribution relative De Loecker et al. (2020) who focus on publicly listed firms or firms in specific sectors.

There is evidence of a positive relationship between intangible capital and markups at the firm and industry level. Among firms, I measure intangible capital-intensity as intangible capital reported in firm financial statements relative to the labor cost. The results imply that a one standard deviation increase in intangible capital-intensity is associated with about 0.3 percentage points higher markups. At the industry level, I measure intangible capital-intensity as intangible capital relative to the cost of labor from the national accounts. The results imply that an increase in intangible capital-intensity by one standard deviation is associated with about 1.8 percentage points higher average industry markups. The magnitude of the relationship between intangible capital and markups is relatively modest but it is still economically significant considering that the average firm markup is only 6 percent of the marginal cost.

I find that aggregate markups have remained low and stable in the Swedish economy over the past two decades. The sales-weighted markup has fluctuated between 6 and 10 percent of marginal cost and the cost-weighted markup follows the same pattern at a slightly lower level. These findings are robust to alternative measures of markups. Notably, they are robust to calibrating a constant output elasticity of labor so that markups only depend on the ratio of revenue to variable costs. This robustness exercise confirms that the ratio of revenue to variable costs has not increased in the data.

To further verify the plausibility of the results I study other macroeconomic trends that are indicators of firm market power. Economic profit is the residual income after payments to labor and capital owners have been accounted for and its presence is evidence of barriers to entry. I find that the economic profit share of value added in the Swedish private sector has remained low and constant, mostly below 5 percent. In addition, the aggregate labor share of value added has remained constant over the past two decades. Market concentration is an often-used proxy for competition which is related to firm market power. I find no significant evidence of an increase of concentration in the sectors for which I can measure the relevant market. In summary, other macroeconomic trends are consistent with the finding of low and constant markups over the past two decades.

From these findings we can draw two conclusions. First, while there is a positive relationship between intangible capital and markups at the firm and industry level, a rise in intangible capital is not a sufficient condition for an increase in markups at the aggregate level. Instead, it is likely that other factors have dominated the development of aggregate markups. Moreover, Sweden is a small open economy and half of its GDP is exported. The second conclusion is that Swedish firms in general are acting on competitive markets with low market power inside and outside of Sweden.

This paper can thus help to discriminate between competing explanations for the rise in market power that has been observed in other countries. In particular for the US, the measured rise in firm markups (De Loecker et al., 2020) has been coupled with a measured decline of the labor share (Karabarbounis and Neiman, 2013) and a rise of income that cannot be attributed to any production factor using standard methods (Karabarbounis and Neiman, 2018). Barkai (2020) interprets this income as economic profit. Several candidate explanations have been put forward to explain these facts. For example, **?** propose that advances in information and communication technologies lower the costs of spanning multiple markets which results in a concentration among the most efficient firms with high markups. De Ridder (2019) propose that some firms have a competitive advantage in exploiting intangible capital and can thus take over the market and charge high markups. Similar to this paper, Crouzet and Eberly (2019) indeed find that intangible capital is positively related to markups among US firms and industries, in particular for the healthcare industry. While Sweden is an increasingly intangibles-intensive economy, I do not measure an increase in markups over the past two decades. This finding casts doubt on a technological shift towards intangible capital as the sole explanatory factor behind an aggregate rise in markups observed in some countries.

2 Theoretical framework

Intangible capital has features that distinguish it from physical capital.[2] First, since intangible capital does not take a physical form, it can be used in many locations simultaneously. For example, a pharmaceutical firm can use the same patent as a basis for production in several plants. This means that intangible capital is scalable and has the properties of fixed costs. Second, intangible capital typically involves some element of innovation and the return on an investment in intangible capital is therefore likely to be uncertain. For example, the outcome of a research and development project is hard to know beforehand. Third, an investment in intangible capital is more likely to be a sunk cost as compared to an investment in physical capital since intangible capital tends to be more firm-specific. For example, investments in marketing and advertising may not have any value to other firms whereas machines and buildings can yield a substantial value on the secondary market.

An implication of uncertainty and scalability is that production based on a successful investment in intangible capital can be expanded at a low marginal cost. For example, a piece of software can potentially be installed on thousands of computers at almost zero marginal cost. Hence, a firm that succeeds in its intangible capital investment can scale up its production or charge high markups relative to other firms. These arguments suggest that firms investing in intangible capital will charge high markups for at least two reasons; 1) to cover the fixed costs of intangible capital, and 2) if they succeed and obtain a low marginal cost relative to other firms. In addition, firms that fail in their intangible capital investment will not produce at a loss but the downside is limited by the possibility of exit. Therefore, if intangible capital is creating a greater dispersion in firm outcomes and we only observe firms that survive, we are likely to observe higher markups in industries where intangible capital is more important. However, these high markups are not necessarily associated with economic profit in the industry as a whole. To determine the presence of economic profit, we need to consider all firms that invest in the industry, not only those that succeed but also those that fail.

In Appendix A, I outline a theoretical framework in line with Melitz and Ottaviano (2008) to analyze the relationship between intangible capital and average industry markups. I assume that the production technology is characterized by a fixed cost of

[2] See Haskel and Westlake (2017) for a discussion of the properties of intangible capital.

intangible capital which is sunk and a degree of uncertainty in terms of the firm marginal cost. In industries where intangible capital is more important in the production technology, each firm needs to pay a higher fixed cost and there is higher variation in terms of firm marginal costs.

In general, the relationship between intangible capital and average industry markups depends both on the level of the fixed cost and the distribution of firm marginal costs. When firm productivity follows a Pareto distribution so that firm marginal costs are distributed inverse Pareto, only the dispersion of marginal cost matters. In this case, the model predicts that industries in which intangible capital is more important in the production technology will be characterized by;

i higher fixed costs of intangible capital relative to the variable costs (a higher intangible capital-intensity),

ii higher average industry markups,

The reason for this prediction is that, with a high cost dispersion, the industry will be dominated by very productive firms that charge high markups, use little variable inputs and pay a low share of income to labor. In the empirical analysis below, I test the prediction of a positive relationship between intangible capital-intensive and markups.

3 Measuring intangible capital

The fact that intangible capital does not take a physical form makes it slighly more difficult to measure relative to other types of capital. In national accounting, capital stocks are measured based on historical cost. The principle of recognizing firm expenditure on intangibles as capital investment has been established over the past two decades. Today, three types of intangibles are included in the national capital stock; R&D, software and artistic originals. In Sweden, data on expenditures on intangible capital are mainly based on surveys of a sample of firms that are used to impute values for the wider population.[3] The national accounts measures of intangible capital have the advantage that they are based on a common definition and cover the entire economy. However, intangibles such as brand value, which can be very important from a firm-perspective, are omitted.

The firm accounting framework covers a broader set of intangible capital as compared to the national accounts. According to the international accounting standards (IAS), intangible capital assets include computer software, licenses, trademarks, patents, films,

[3] See Appendix B.1 for details on the data collection.

copyrights but also goodwill acquired in a business combination. It is common practice to treat expenditures on externally acquired intangible capital as capital investment. However, the treatment of internally developed intangible capital varies across countries and across time. For example, US firms are not allowed to treat expenditure on internally developed intangible capital as investment. In Sweden, firms have the option but not the obligation to treat expenditure on internally developed intangibles as capital investment and there are reasons to believe that firm choices are partly guided by strategic objectives. For example, start-up firms that are not yet profitable may find it optimal to account for this expenditure as investment in order to support equity values. In contrast, more profitable firms may find it optimal to keep profits and thus taxes low by accounting for this expenditure as costs. This raises concerns about the comparability of intangible capital measures across firms and across time. In addition, small firms that have opted for a simplified accounting framework do not have the right to recognize internally developed intangible capital.[4]

A comparison between intangible capital in the national accounts and intangible capital in firm accounting shows large differences between the two measures. The national accounts data is available at 2-digit ISIC/NACE level so I aggregate firm-level data to the same level. For the median industry observation, aggregate intangible capital reported in firm financial statements is only one-fifth of the median intangible capital reported in the national accounts. The correlation between the two measures is only 0.20. This comparision suggests that there is underreporting of intangible capital in firm financial statements. Further details on the measurement of intangible capital and a comparison between the data sources are provided in Appendix D.

3.1 A measure of intangible capital-intensity

The theoretical framework summarized in Section 2 predicts that the higher is the importance of intangible capital in the industry technology, the higher will be the ratio of total fixed costs of intangible capital relative to variable costs in the industry. To measure this ratio, I use the stock of intangible capital relative to the cost of labor and call this measure intangible capital-intensity.

$$\frac{IC}{wL}. \tag{1}$$

At the industry level, I use intangible capital from the national accounts relative

[4]See Appendix B.3 for details on the accounting rules.

to the labor cost from the national accounts to measure intangible capital-intensity. The underlying industry unit is the 2-digit ISIC/NACE industry, but smaller industries are grouped together. In total, there are 52 industries spanning the entire private sector from agriculture and manufacturing to services. Despite the limitations of the intangible capital measure reported in firm financial statements, it is the only measure of intangible capital available for a large number of firms. Therefore, at the firm level, I use intangible capital from firm financial statements relative to the labor cost as a measure of intangible capital-intensity.

4 Measuring markups

I estimate firm markups according to the production approach proposed by De Loecker and Warzynski (2012) building on work by Hall (1988). This method is based on firm cost-minimization and relies on that we observe the cost of a variable production factor and can identify its output elasticity.

In consistency with the theoretical framework, I assume that intangible capital is a fixed cost that does not directly enter the production function which is Leontief in intermediate inputs.[5] This production function can be considered a model of technology in the short run when there is no substitutability between capital or labor and intermediate inputs, respectively. For example, a certain amount of metal is needed to produce one mobile phone. Importantly, the Leontief assumption addresses the identification problem pointed out by Gandhi et al. (2011). It is also the production function used by De Loecker et al. (2020) when separating between labor and intermediate inputs. For firm i at time t, we have

$$Y_{it} = min[e^{\beta_0} K_{it}^{\beta_1} L_{it}^{\beta_2} e^{\omega_{it}}, \beta_3 M_{it}] \tag{2}$$

where Y_{it} corresponds to gross output, L_{it} is labor input, K_{it} is a measure of (physical) capital inputs, M_{it} is intermediate inputs and ω_{it} is firm-specific productivity.

The firm cost-minimization problem, outlined in Appendix C, results in the markup

$$\mu_{it} \equiv \frac{P_{it}^Y - MC_{it}}{MC_{it}} = \beta_2 \frac{P_{it}^Y Y_{it}}{w_{it} L_{it} + \beta_2 p_{it}^M M_{it}} - 1. \tag{3}$$

[5]The theoretical model in Section 2 does not distinguish between the different variable production factors. However, to identify markups, I model the variable costs of capital, labor and other intermediate inputs separately. Introducing capital in the Melitz-Ottaviano model does not change its insights as long as capital is owned by workers, each of them holding a balanced portfolio so that they are only interested in the expected returns as pointed out by Bellone et al. (2009) and Corcos et al. (2007).

where firm revenue ($P_{it}^{Y} Y_{it}$), the labor cost ($w_{it} L_{it}$) and costs of intermediate inputs ($p_{it}^{M} M_{it}$) can be directly observed in the data but the output elasticity β_2 needs to be estimated. For each 2-digit ISIC industry, I estimate the production function in log form

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \tau_t + \omega_{it} + \epsilon_{it} \quad (4)$$

where ϵ_{it} is an unexpected productivity shock. Time fixed effects τ_t are included to account for the fact that productivity is growing over time.

Identification of the parameters follows Ackerberg et al. (2015) and relies on assumptions on the relationship between persistent productivity ω_{it} and intermediate inputs. The necessary conditions are that ω_{it} is the only unobservable entering the firms' intermediate input demand function and that this function is strictly increasing in ω meaning that, conditional on capital and labor, more productive firms use more intermediate inputs.[6] I estimate the parameters by iterative GMM using the procedure of "concentrating out" parameters that depend linearly on other parameters. To increase the probability of arriving at a global optimum, I iterate over a large number of initial parameter values in the optimization algorithm and choose the estimation which results in the lowest function value.

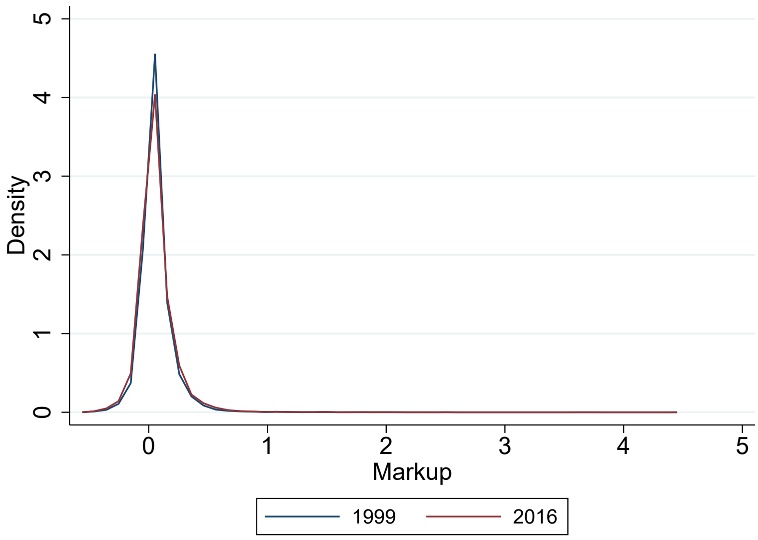
4.1 Data

To estimate markups, I use data from administrative records based on firm financial statements covering all non-financial Swedish firms between 1997 and 2016. The observed firm unit is most often the legal unit but sometimes several legal units are grouped into an economic unit. For production function estimation, gross output is measured by sales, the capital input is measured by the book value of firm capital and the labor input is measured by the cost of labor aimed at capturing a quality-adjusted labor input. The variables are deflated to reflect the fact that the production function is a real concept.

There are about 900 000 firms in Sweden but many are inactive or serve purely legal purposes. To ensure that I am focusing on economically active firms, I restrict the sample to firms with at least 4 employees and sales of at least SEK 250 000 (approximately USD 30 000). In total, the sample used for markup estimation includes a little over one million firm-year observations. Median sales amount to about SEK 10 million (about USD 1 million) but the firm size distribution is right-skewed and mean firm sales amount to SEK 70 million (about USD 10 million). The median firm in the sample does not report any intangible capital, reflecting the fact that small firms opt for simplified accounting

[6] See Appendix C.1 for details on the identification.

Figure 2: Distribution of firm markups



Notes: Markup over marginal cost.

rules. The average firm reports SEK 2 million of intangible capital. Additional details on variable definitions and summary statistics are found in Appendix D.

5 Results

In this section, I first study the relationship between intangible capital and markups at the firm and industry level. Second, I study the evolution of aggregate markups and conclude with robustness analysis.

5.1 Markups and intangible capital

5.1.1 Firm markups and intangible capital

The firm markup distribution has been relatively constant over time. Figure 2 shows no major difference between the markup distributions in the years 1999 and 2016. The mean markup in the sample is 0.06 and 95 percent of firms have markups between -0.12 and 0.30. There is however a long right tail with markups of up to 450 percent of marginal cost. The negative markups, meaning that price would be lower than marginal cost, are primarily found in the agriculture and forestry sectors.

To test the relationship between intangible capital and firm markups, I regress markups on intangible capital-intensity, IC/wL. Markups are however likely to vary across industries and over time for reasons other than the importance of intangible capital in the production technology. For example, markups are likely to vary across industries due to differences in competition. Markups are also likely to vary across time due to aggregate shocks and trends in technology and the competitive environment that are independent of intangible capital. Moreover, physical capital is generally considered a semi-fixed cost and it is plausible that markups over marginal costs are also positively related to physical capital. This motivates the inclusion of physical capital-intensity K/wL as a control variable. The theoretical model in Appendix A predicts that large firms will charge higher markups which motivates the inclusion of firm size in terms of sales as a control variable. Therefore, the regression specification is given by

$$\mu_{it} = \zeta_0 + \zeta_1(IC/wL)_{it} + \zeta_2(K/wL)_{it} + \zeta_3 log(Sales)_{it} + \psi_j + \tau_t + t_s + u_{jt} \tag{5}$$

where ψ_j denotes industry fixed effects, τ_t denotes time fixed effects and t_s denotes a time trend at sector level. In addition, the measure of intangible capital may also vary across firms due to differences in accounting practices. Therefore, I also report a specification using firm fixed effects.

Table 1 shows a positive and statistically significant relationship between intangible capital-intensity and markups. When studying the variation between the two variables within industries, the results imply that a one-unit increase in intangible capital-intensity is associated with 1.2 percentage points higher markups. The various ways of accounting for time-specific effects in columns 1-3 do not change the coefficient on intangible capital-intensity. This result can however partly be explained by firm-specific effects. When studying the variation within firms, a one-unit increase in intangible capital-intensity is associated with a 0.9 increase in markups as reported in column 4. In accordance with theoretical predictions, the physical capital-intensity and firm sales are also positively related to firm markups.

The magnitude of the measured correlation between intangible capital-intensity and markups is relatively small. For example, a one standard deviation increase in intangible capital-intensity (0.31) is associated with a 0.3 percentage point increase in markups according to the specification with firm fixed effects. At the same time, this increase is still economically significant since it corresponds 6 percent of the average firm markup. As discussed above, intangible capital is measured with error which implies that its regression coefficient is biased towards zero. Additional comparisons of different measures of intangible capital-intensity could possibly help us evaluate the size of the measurement

Table 1: Regression - firm-markups and intangible capital-intensity

	(1)	(2)	(3)	(4)
Intangible capital-intensity, IC/wL	0.0121***	0.0121***	0.0121***	0.00867***
	(0.000479)	(0.000479)	(0.000479)	(0.000449)
Physical capital-intensity, K/wL	0.0153***	0.0152***	0.0152***	0.0110***
	(0.0000662)	(0.0000664)	(0.0000664)	(0.000122)
log(Sales)	0.00633***	0.00634***	0.00632***	0.0670***
	(0.000122)	(0.000122)	(0.000122)	(0.000358)
Observations	868057	868057	868057	848201
R^2	0.133	0.134	0.135	0.635
year fe	yes	yes	no	no
industry fe	yes	yes	yes	yes
sector trends fe	no	yes	no	no
sector-year fe	no	no	yes	yes
firm fe	no	no	no	yes

Notes: The dependent variable is the firm markup. Coefficients refer to a one-unit increase of the explanatory variables. Industry refers to the 2-digit ISIC sector level but smaller industries are grouped together. Sector refers to the 1-digit ISIC sector level. Standard errors in parenthesis. Panel data of firms between 1999 and 2016.

error.

5.1.2 Industry markups and intangible capital

The theoretical framework predicts that average industry markups will be positively related to intangible capital-intensity. This section aims at testing this correlation. The weighted average of firm markups is calculated for each industry j and year t as

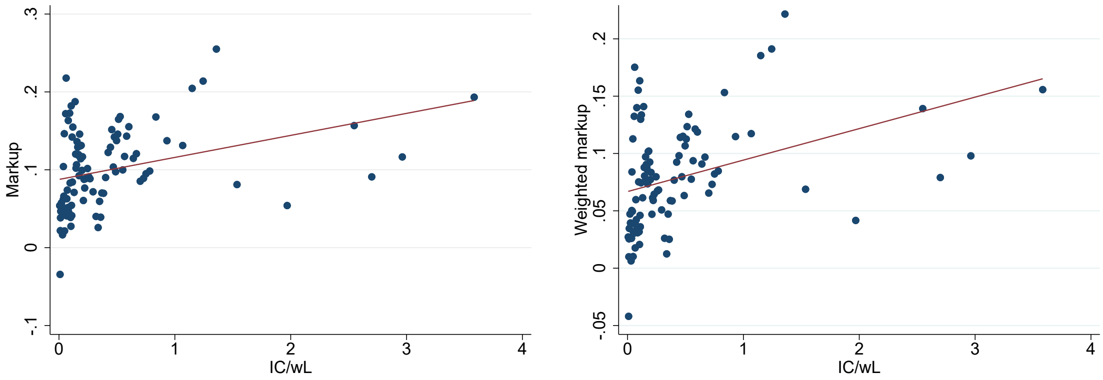
$$\bar{\mu}_{jt} = \sum_i \mu_{ijt} \times weight_{ijt} \tag{6}$$

where $weight_{ijt}$ denotes the weight of firm i in industry j at time t. I use two sets of weights; 1) the share of each firm's sales in total industry sales and 2) the share of each firm's cost in total industry cost. Here I consider the cost of labor and the cost of intermediate inputs but not the cost of capital since its calculation results in missing values for many industries.[7] The median sales-weighted markup is 0.07 and the cost-weighted markup somewhat lower, 0.06. The median intangible capital-intensity is only 0.19 but the variation is large, one standard deviation corresponds to 0.62. The summary statistics are presented in Appendix D.3.

There is a positive relationship between intangible capital-intensity and average industry markups in the panel of industry observations as shown in Figure 3. For both

[7]See details on factor share in Appendix F.

Figure 3: Markups and intangible capital-intensity



(a) Sales-weighted markups

(b) Cost-weighted average markups

Notes: Binned scatter plots. The data is grouped into 100 equally sized bins. Each data point in the graph represents the average of the x-axis and the y-axis variables within each bin. The regression line is displayed in red. Panel data on industries between 1999 and 2016.

sales-weighted and cost-weighted markups, the positive correlation is visible among industry observations with moderately high intangible capital-intensity. However, it is not necessarily the case that industries with very high intangible capital-intensity show higher industry markups.

To examine this relationship more formally, I regress average industry markups on intangible capital-intensity. Markups vary over time and across industries for reasons other than intangible capital-intensity. Importantly, it is likely that markups vary over time due to underlying trends in technology and the competitive environment that are independent of intangible capital. Therefore, I aim at controlling for such broad trends at the 1-digit sector level. Following the motivation in section **??**, a complete regression specification is given by

$$\mu_{jt} = \zeta_0 + \zeta_1 (IC/wL)_{jt} + \zeta_2 (K/wL)_{jt} + \tau_t + t_s + \psi_j + u_{jt} \tag{7}$$

where τ_t denotes time fixed effects, t_s denotes a time trend at sector level ψ_j denotes industry fixed effects.

The results for the sales-weighted markups are shown in Table 2.[8] It shows a positive and statistically significant relationship between intangible capital-intensity and markups. The results imply that an increase in intangible capital-intensity by one unit

[8]The results for the cost-weighted markup are found in Appendix E.

Table 2: Regression - Sales-weighted markups and intangible capital-intensity

	(1)	(2)	(3)	(4)
Intangible capital-intensity, IC/wL	0.0318***	0.0363***	0.0332***	0.0343***
	(0.00604)	(0.00552)	(0.00538)	(0.0103)
Physical capital-intensity, K/wL	0.00238***	0.00213***	0.00185***	-0.00345**
	(0.000272)	(0.000294)	(0.000302)	(0.00106)
Observations	778	778	778	778
R^2	0.129	0.426	0.603	0.942
year fe	yes	yes	no	no
sector trends	no	yes	no	no
sector-year fe	no	no	yes	yes
industry fe	no	no	no	yes

Notes: The dependent variable is the unweighted average industry markup. Coefficients refer to a one-unit increase in the explanatory variables. Industry refers to the 2-digit ISIC sector level but smaller industries are grouped together. Sector refers to the 1-digit ISIC sector level. Standard errors in parenthesis. Panel data on industries between 1999 and 2016.

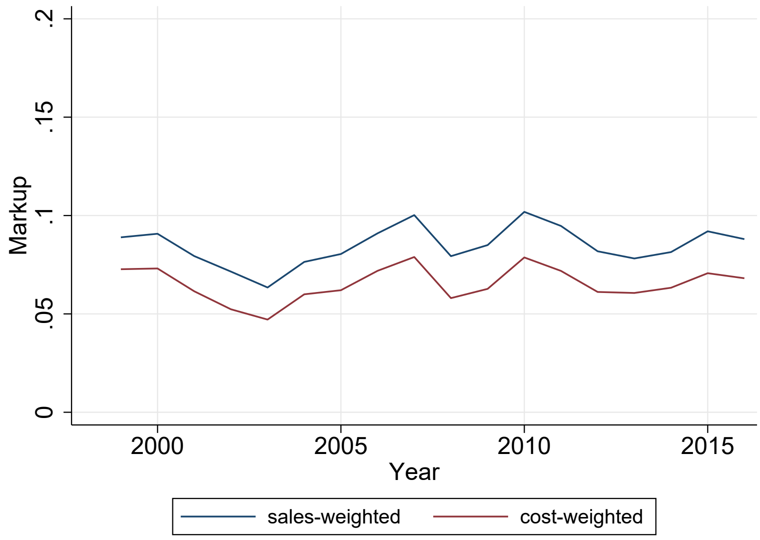
is associated with an increase in the average industry markups of about 3 percentage points, that is 3 percent of marginal cost. The inclusion of a linear time-trend in column 2 or sector-year fixed effects, which is a more flexible specification, in column 3, does not significantly change the coefficient. The result does not only stem from the variation in intangible capital across industries. Column 4 shows that it remains unchanged when studying the variation in intangible capital and markups within industries over time.

The results imply that a one standard deviation increase of intangible capital-intensity (0.21) corresponds to about 1.8 percentage points higher markups. For example, when comparing the industry for electricity production with an intangibles-intensity of 0.6 to the telecommunications sector with an intangibles-intensity of 1.2, we would expect the latter to have about 1.8 percentage points higher markups. One the one hand, this increase is relatively modest. On the other hand, it is still economically significant considering that it corresponds to one quarter of the median industry markup.

5.2 Aggregate markups

Has an increase in intangible capital at the aggregate level translated into an increase in markups at the aggregate level? Figure 4 shows aggregate markups of non-financial firms in Sweden. We see that aggregate markups have remained low and stable over the past two decades. The sales-weighted markup has fluctuated between 6 and 10 percentage points and cost-weighted markup follows a similar pattern but at a slightly lower level. This result stands in contrast to what has been found among publicly listed firms in the US. First, the levels are different. For example, De Loecker et al. (2020)

Figure 4: Aggregate economy markups



Notes: Weighted average of non-financial firms in Sweden.

and Traina (2018) estimate current aggregate markups to 61 percent and 50 percent of the marginal cost. Second, the trend is different. De Loecker et al. (2020) find that markups among publicly listed firms in the US have increased by 40 percent of marginal cost between 1980 and the present day. They find a particularly strong increase over the last two decades which is largely driven by a small fraction of firms with very high markups. Figure E.1 depicts sales-weighted average markups for the firms with the highest markups corresponding to 10 percent of sales/cost in my sample. It shows that there is no significant markup increase among these top markup firms. Figure E.2 shows sales-weighted markups for various sectors in the economy. Notably, markups have been stable in the large manufacturing sector as well as in most other sectors.

From these findings we can draw two conclusions. First, an increase in intangible capital at the aggregate level need not be associated with an increase in markups at the aggregate level. Moreover, the Swedish economy is open to trade and half of its GDP is exported every year. The second conclusion is that firms are acting on competitive markets with low market power inside and outside of Sweden.

5.3 Alternative markup measures

The main markup results are based on the estimation of the output elasticity of labor. Here, I explore two alternative markup estimates; 1) markups based on the estimation of an output elasticity on labor and intermediate inputs jointly as in De Loecker et al. (2020) and 2) markups based on an output elasticity of labor calibrated to 0.85. In addition, my main measure of intangible capital-intensity relates a stock variable (intangible capital) to a flow variable (the labor cost). A potential drawback with this measure is that, when shocks hit the economy, the capital stock may adjust at a slower rate than the variable cost. Hence, the intangible capital-intensity measure may vary for other reasons than variation in production technologies. Therefore, I also report the results based on an alternative measure of intangible capital-intensity, intangible capital relative to total capital.

Table E.2 shows the firm-level results using these alternative measures for the most restrictive specification including firm fixed effects. It shows that the main results are not sensitive to alternative markup estimates. An increase in intangible capital-intensity by one unit is still associated with an increase in markups by about 0.8 percentage points. In contrast, intangible capital in proportion to total capital, is negatively associated with firm markups. The estimated coefficient is very small however and barely statistically significant. Similarly to the firm-level results, industry-level results do not change much using alternative markup measures. If anything, the correlation is higher as seen in Table E.3. The regression coefficient from the specification bundling labor and intermediate inputs is 0.05 compared to around 0.03 in the main specification. The relationship between intangible capital as a share of physical capital and markups is positive but not statistically significant.

Figure 5 shows aggregate markups using the two alternative specifications. When estimating a joint output elasticity on labor and intermediate inputs I find that markups are trending downwards. The aggregate sales-weighted markup is generally below 5 percent of marginal cost which is lower than the main result. This discrepancy point to the sensitivity of markup measures to the underlying assumptions. The estimation of a joint output elasticity on labor and intermediate inputs does indeed result in an identification problem as pointed out by Gandhi et al. (2011). The second robustness exercise, assuming a constant output elasticity on labor, results in very similar markups compared to the main result. The sales-weighted aggregate markup is roughly constant at 0.10 and the cost-weighted markup follows the same pattern but is about 2 percentage points lower. This specification implies that markup patterns are only driven by the ratio of revenue to variable costs. The results confirm that there is no increase in the ratio of output relative to variable costs over time.

Figure 5: Alternative markup measures: aggregate trends

(a) Bundling labor cost and materials

(b) Constant output elasticity

Notes: In panel a), a joint output elasticity on labor and intermediate inputs is estimated assuming a Cobb-Douglas production function. In panel b) the production function is still given by Equation 2 but the output elasticity on labor is calibrated to 0.85. Weighted average of private non-fiancial firms in Sweden.

6 Other macroeconomic trends

The low and constant aggregate markups suggest that firms are acting on competitive markets inside and outside of Sweden. To assess the plausibility of this result, I provide evidence on other macroeconomic trends which are indicators of firm market power. First, I study the evolution of the labor share and the profit share of income in the Swedish economy. Second, I study market concentration which under certain conditions can be an indicator of competition.

6.1 Factor shares of income

6.1.1 Estimating factor shares

In general, value added can be accounted for by the cost of labor (wL), the user cost of capital (RK) and economic profit (Π). I estimate factor shares of income using industry-level data. For each industry j and time t, we have

$$VA_{jt} = wL_{jt} + \sum_{n=1}^{N} R_{jtn}K_{jtn} + \Pi_{jt} \tag{8}$$

where n denotes the type of capital. Here I consider two types of physical capital, machines and buildings, and two types of intangible capital, R&D and software.[9] Data on capital stocks, labor cost, and value added at the industry level are obtained from the national accounts.

Unlike the cost of labor, the user cost of capital, and hence the economic profit, cannot be directly observed in the data. The main reason is that the market rental rates for capital are rarely observable since many firms own, rather than rent, their capital. Instead, a rental rate of capital is commonly constructed using the formula developed by Hall and Jorgenson (1967) based on a no-arbitrage condition between renting and owning capital. This is the approach taken by Karabarbounis and Neiman (2018) and Barkai (2020) which I also follow here. For each capital type n we have the rental rate

$$R_{jtn} = \delta_{jtn} - i_{jtn} + r_{jt} \tag{9}$$

where δ_{jtn} is the depreciation rate, i_{jtn} is the inflation rate for the price of capital goods, $\frac{\Delta p_{j,tn}}{p_{j,t-1,n}}$, and r_{jt} is the required return on capital. Estimates of price inflation rates and depreciation rates for capital goods are obtained from Statistics Sweden.[10] I assume that the required return on capital is given by a weighted average of the cost of debt and equity capital

$$r_{jt} = r_{D,t}\frac{D_{jt}}{D_{jt} + E_{jt}} + r_{E,t}\frac{E_{jt}}{D_{jt} + E_{jt}} \tag{10}$$

where $r_{D,t}$ is the average corporate borrowing rate on bank loans and $r_{E,t}$ corresponds to $r_{D,t}$ plus a risk premium of 5 percentage points. This required return on capital does not differ across capital types. However, if a larger share of equity financing for certain types of capital implies higher financing costs, these higher financing costs are reflected in the required return measure.

Given the calibration of the rental rate, the user cost of capital and factor shares of value added can be calculated. The average rental rate of intangible capital across industries is 29 percent of the capital stock. For each industry j and time period t, the

[9] I ignore the capital type "artistic originals" which is a minor capital item in most industries.

[10] Additional details on the data are found in Appendix D.

labor share, the capital share and the profit share are given by

$$s_{L,jt} = \frac{wL_{jt}}{VA_{jt}}, \tag{11}$$

$$s_{K,jt} = \frac{\sum_{n=1}^{N} R_{jtN}K_{jtN}}{VA_{jt}}, \tag{12}$$

and

$$s_{\Pi,jt} = \frac{\Pi_{jt}}{VA_{jt}} = 1 - s_{L,jt} - s_{K,jt}. \tag{13}$$

6.1.2 Aggregate labor share and profit share

Figure 6 shows the labor share and the profit share in the Swedish private sector between 1997 and 2016. In contrast to the findings by Karabarbounis and Neiman (2018) and Barkai (2020) for the US, there is no evidence of a declining labor share and an increasing profit share in the Swedish economy. The labor share is stable around 0.65 and if anything there is a slight increase during this time period. The measured profit share is low, mostly below 5 percent of value added. Somewhat surprisingly, it increases during the global financial crisis but reverts to an even lower level after 2009. The finding of low economic profit is in line with the finding of low markups and supports the conclusion that Swedish firms do in general act on competitive markets.

In Appendix F, I study whether the measured economic profit at industry level is associated with intangible capital in the national accounts. In the pooled cross-section of industry observations, an increase in intangible capital-intensity by one unit is associated with an 8 percentage points higher profit share. However, this positive relationship is not necessarily present when studying the variation in the two variables over time within a given industry. It is possible that this positive correlation between intangible capital and economic profit is due to undermeasurement of the intangible capital stocks in the national accounts. Such an undermeasurement would imply that income that in fact is a competitive compensation to capital owners would be incorrectly classified as the residual economic profit. I find that if the true capital stocks were on average 15 percent higher than the measured capital stocks, the positive relationship between intangible capital and markups would disappear. In summary, further analysis is required to establish whether intangible capital is related to economic profit at the industry level.

Figure 6: Private sector labor share and profit share over time

(a) Labor share

(b) Profit share

Notes: Shares of value added. Aggregates of private sector industry level data from the national accounts.

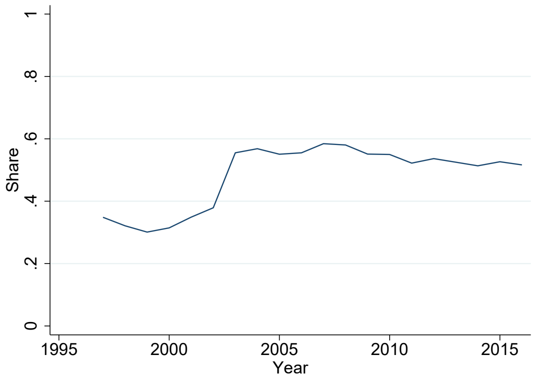
6.2 Concentration

Another metric related to firm market power is market concentration, notably sales concentration within an industry. For example, Barkai (2020) argues that higher concentration is associated with a decrease in competition which allows firms to charge higher markups. Following this logic, we would expect that no change in markups is associated with no change in market concentration. There is however no consensus view on how concentration is related to the degree of competition and market power. Autor et al. (2020) argue that an increase in product market competition has lead to a concentration of sales among the most productive firms.

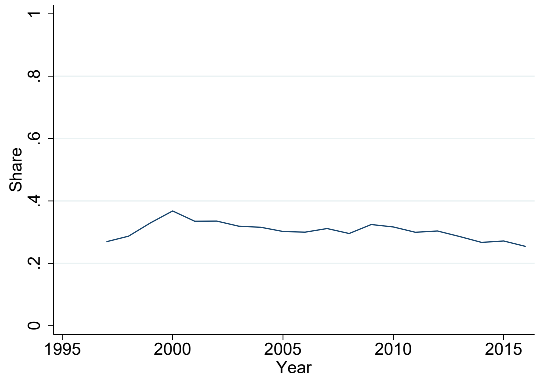
The general challenge with measuring market concentration is defining the market. Here, I measure market concentration as the share of the 4 firms with the largest sales in total industry sales for 4-digit ISIC/NACE industries in Sweden following Autor et al. (2020). This is a relevant measure of market concentration for industries that are oriented towards the domestic market but less so for industries that are oriented towards exports. For multinational firms with a global presence it would be more relevant to measure market share relative to the total world market.

Figure 7 shows concentration measures for a number of sectors that can be assumed to be focused on the domestic market. Concentration has remained roughly constant between 1997 and 2016 except for the utilities sector where there was a major increase in the year 2004. This overall constancy of the levels of concentration is consistent with the finding of constant markups over the same time period. Figure E.3 shows sales concentration for the export-oriented industries.

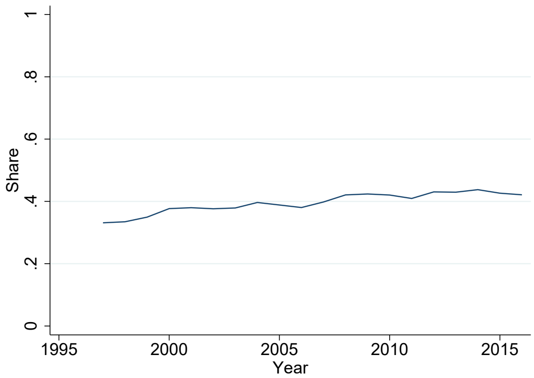
Figure 7: Average sales concentration



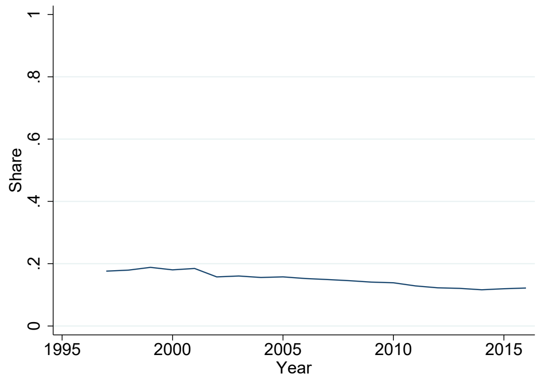
(a) Utilities



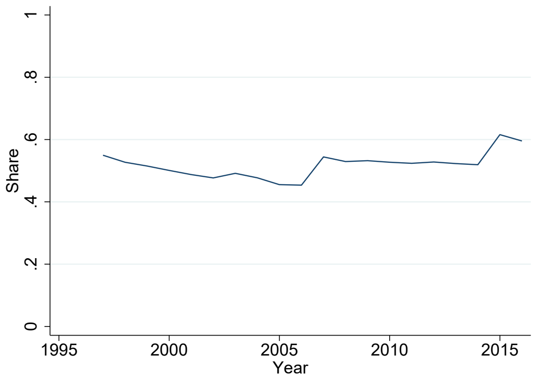
(b) Construction



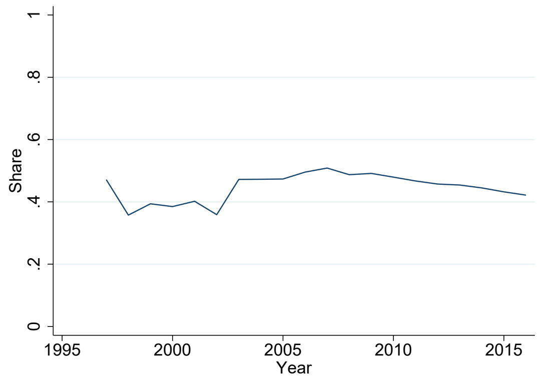
(c) Trade



(d) Hotels and restaurants



(e) Information and communication services



(f) Other services

Notes: Sales-weighted concentration at 1-digit ISIC/NACE sectors. Concentration measured as the share of the 4 firms with the largest sales in total industry sales for 4-digit ISIC/NACE industries.

7 Concluding discussion

This paper contributes to the current discussion on the consequences of a rise in intangible capital and the reasons for an increase in markups observed in several countries, notably the US. The paper provides evidence of a positive relationship between intangible capital and markups at the firm and industry level but documents constant markups in the aggregate economy. The rise of intangible capital coupled with constant markups suggests that a shift to more intangibles-intensive technologies is not the sole explanatory factor behind an increase in markups observed in other countries.

The results in this paper call for an explanation of the different markup trends observed in Sweden and the US. Part of the explanation may come from differences in measurement. While studies of the US have focused on publicly listed firms or specific sectors of the economy, I estimate markups using data on all Swedish firms with at least 4 employees. Another measurement challenge is the correct allocation of income of intangibles-intensive multinational firms across countries. Since intangible capital does not take a physical form, there has been a potential for multinational firms to transfer intangible capital and associated profit flows to countries with relatively low corporate taxes, see, for example, Guvenen et al. (2017). On the one hand, this speaks in favor of markup measurement at the group level. On the other hand, these firms may span several disparate activities that have very different output elasticities or demand functions required for markup estimation.

An important remaining question is to what extent the difference in markups observed in Sweden and the US stems from fundamental differences in competition and firm market power. For example, Gutiérrez and Philippon (2018) find that markets in the European Union have become more competitive than markets in the United States. If so, there may be room for policies to improve outcomes in countries that have witnessed a large increase in firm markups and market power.

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A Industry model

There is a large pool of potential entrants that can freely enter into the industry. To enter, each firm must incur a fixed cost f of investment in intangible capital. The cost f is sunk and cannot be recovered at a later stage. The investment results in an uncertain outcome for the firm-specific marginal cost of production c_i, which is drawn from a known distribution $G(c)$ with support $[0, c_M]$. After observing the cost draw, firms decide whether to produce or exit from the industry. From the total set of firms I, there is a continuum of firms of measure N_E that enters and invests and a measure N that eventually produces output. Each firm produces a distinct variety i of the industry good.

Consumers have preferences over a numeraire good y and industry varieties. The representative consumer's utility function is given by

$$U = y + \alpha \int_{i \in I} q_i di - \frac{1}{2}\eta(\int_{i \in I} q_i di)^2 - \frac{1}{2}\gamma \int_{i \in I} q_i^2 di \tag{14}$$

where the parameters α and η shift the demand for the industry good relative to the numeraire good. The parameter γ determines the degree of substitutability between industry varieties. When $\gamma = 0$ products are perfect substitutes and consumers care only about total consumption of the industry good.

Consumers maximize the utility given by (14) subject to the budget constraint[11]

$$\int_{i \in I} p_i q_i di + y = w_i. \tag{15}$$

This utility maximization results in the following linear demand for each variety of the industry good

$$q_i = \frac{\alpha}{\eta N + \gamma} - \frac{1}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{1}{\gamma} \bar{p} \tag{16}$$

where p_i is the price of variety i. The average price for industry varieties is given by $\bar{p} \equiv \frac{\int p_i d_i}{N}$. Demand falls to zero if $p_i = \frac{1}{\eta N + \gamma}(\gamma \alpha + \eta N \bar{p})$ so this is the maximum price, p_{max}, that firms can charge and still sell a nonnegative quantity. After learning its marginal cost of production, a firm finds its optimal price by solving

$$\max_{p_i} [p_i - c_i] q_i(p_i) \tag{17}$$

[11]There is a unit wage determined by the numeraire good sector.

subject to q_i given by (16) and taking N and $\bar{p}$ as given. Thus, the industry is monopolistically competitive. The price that maximizes a firm's profit is

$$p_i = \frac{1}{2}\frac{\gamma\alpha}{\eta N+\gamma} + \frac{1}{2}\frac{\gamma\eta N}{\eta N+\gamma}\frac{\bar{p}}{\gamma} + \frac{1}{2}c_i. \tag{18}$$

Inserting (18) into (16), we get the operational profit function

$$\pi_i = \frac{1}{4\gamma}\Big(\frac{\alpha\gamma}{\eta N+\gamma} + \frac{\eta N}{\eta N+\gamma}\bar{p} - c_i\Big)^2. \tag{19}$$

Firms whose optimal price in (18) exceeds their cost draw will decide to produce whereas firms that cannot cover their marginal cost will exit the industry. The marginal producer is a firm which can make zero profit by charging the highest possible price, p_{max}. We denote the cost of this firm by c_D and note from (19) that it is given by

$$c_D = \frac{\alpha\gamma}{\eta N+\gamma} + \frac{\eta N}{\eta N+\gamma}\bar{p}. \tag{20}$$

All performance measures of a producing firm can be expressed as functions of the cutoff cost c_D. In particular, the firm's net markup relative to the marginal cost is given by

$$\mu(c_i) = \frac{p_i - c_i}{c_i} = \frac{c_D - c_i}{2c_i} \tag{21}$$

so firms with lower cost draws charge higher markups. The average industry markup is given by the integral of firm markups from the lowest cost level to the cutoff cost c_D

$$\bar{\mu} = \int_0^{c_D} \frac{(c_D - c)}{2c} dG(c)/G(c_D). \tag{22}$$

By substituting (20) into (19), the operating profit of a producing firm is given by

$$\pi(c_i) = \frac{1}{4\gamma}(c_D - c_i)^2. \tag{23}$$

Before entry, a firm compares the expected operational profit from entering to the fixed cost of investment in intangible capital, f. With free entry, firms will enter the industry until the expected operational profit is equal to the fixed cost

$$E(\pi) = \int_0^{c_D} \pi(c)dG(c) = \int_0^{c_D} \frac{1}{4\gamma}(c_D - c)^2 dG(c) = f. \tag{24}$$

Using (24), we can solve for the cutoff cost level c_D. This free entry condition has an important economic implication summarized in the following proposition.

Proposition 1: *The total fixed cost of entrant firms is exactly equal to the total operating profits of surviving firms.*

Proof: The relationship between entering firms and producing firms is given by

$$N_E = \frac{N}{G(c_D)}. \tag{25}$$

From (24) we have that the total expected operational profit in the industry is equal to the total fixed cost

$$N_E \int_0^{c_D} \pi(c)dG(c) = N_E f. \tag{26}$$

By substituting (25) into (26) it follows that the total expected operational profit is equal to the operational profit of producing firms

$$N_E \int_0^{c_D} \pi(c)dG(c) = N \int_0^{c_D} \pi(c)dG(c)/G(c_D). \tag{27}$$

Hence, the total fixed cost of entering firms is equal to the total operating profit of producing firms

$$N_E f = N \int_0^{c_D} \pi(c)dG(c)/G(c_D) \tag{28}$$

Q.E.D. This result holds irrespective of the underlying distribution of the firm marginal cost. It is important for the analysis of factor shares below.

A.1 The importance of intangible capital and markups

This section studies what happens to average industry markups when intangible capital becomes more important in the industry production technology. I model a higher importance of intangible capital in the industry technology as a higher level of the fixed cost f and a higher variation in terms of firm marginal costs.

A.1.1 General distribution

What happens to markups when the fixed cost f of intangible capital increases? From (24), we see that f is positively related to the cutoff cost-level c_D. The logic behind this result is that if we consider an industry with a fixed number of potential entrants, a higher fixed cost will lead to fewer firms attempting to enter the industry.[12] With a lower number of competitors, the demand curve for an individual firm will shift out and less productive firms will be able to survive. Applying Leibniz' integral rule to the average industry net markup in (22), we get

$$\frac{\partial \bar{\mu}}{\partial c_D} = \int_0^{c_D} \frac{1}{2c} dG(c)/G(c_D) - \int_0^{c_D} \frac{(c_D - c)}{2c} \frac{dG(c)G'(c_D)}{G(c_D)^2}. \tag{29}$$

The first term captures a positive effect on average markups because firms that have sufficiently low costs to survive under the initial c_D will raise their markups. The second term captures a negative effect on average markups from the survival of less productive firms. Which of these two effects that dominates depends on the underlying distribution of firms' marginal costs. When the effect of an increase in the cutoff cost c_D on survival is small (the second term is small), the average markups will increase with the fixed cost. Autor et al. (2020) show that if the distribution of firm productivity $1/c$ is log-concave in $\log(c_D)$, then an increase in c_D will lead to higher average industry markups.[13]

What happens to markups when a higher importance of intangible capital in the industry technology results in a greater variation in firm marginal costs? Let us consider a cost distribution $F(c)$ which is a mean-preserving spread of the distribution $G(c)$. A firm's markup $\mu(c)$ is a convex function of its marginal cost. Hence, for a given cutoff cost level c_D, the average industry markup under the more dispersed distribution $F(c)$ is greater to or equal to the average industry markup under $G(c)$:

$$\int_0^{c_D} \mu(c) dF(c) \geq \int_0^{c_D} \mu(c) dG(c). \tag{30}$$

The intuition behind this result is that with an increased cost dispersion, firms that draw a low cost will be further away from the cutoff and will therefore enjoy higher markups. At the same time, firms that obtain high cost draws will exit and do not affect the average industry markup. However, the increase in markups and operating profits will attract more firms to enter the industry and this will be a force putting downward pressure on c_D. From above, we know that a change in c_D can imply higher or lower markups.[14] To obtain sharp predictions for how an increased cost dispersion affects the average industry markups, we need to know the underlying distribution of the firms'

[12] This reasoning is borrowed from Syverson (2004).

[13] This is a local condition, see Appendix A1 of Autor et al. (2020) building on work by Arnaud Costinot.

[14] It can be noted that in a Cournot model with a fixed number of firms, a larger cost variation will lead to a higher markup (and profit); see Tirole (1988) page 223.

marginal costs.

A.1.2 Pareto distribution

Firm productivity is typically found to be right-skewed, with a large number of firms with low productivity and a smaller number of highly productive firms. Commonly found distributions are either a Pareto distribution or a log-normal distribution; see for example Head et al. (2014) and Amand and Pelgrin (2016). Let us assume that firm productivity draws $1/c$ follow a Pareto distribution with the lower bound $1/c_M$ and shape parameter $k \geq 1$.[15] This is equivalent to assuming that marginal cost draws are distributed inverse Pareto. With free entry, the equilibrium condition (24) now results in the cutoff cost level

$$c_D = (2(k+1)(k+2)\gamma c_M^k f)^{\frac{1}{k+2}}. \quad (31)$$

The assumption that a higher importance of intangible capital in the industry technology results in more variation in terms of firm marginal costs translates into the shape parameter k decreasing with the importance of intangible capital. The coefficient of variation of firm marginal costs

$$\frac{\sigma_c^2}{E(c)} = \frac{c_M}{(k+1)(k+2)} \quad (32)$$

does indeed increase when k is decreasing for a given c_M.

Proposition 2: *When firm marginal costs follow an inverse Pareto distribution, average industry markups are higher in industries with a greater cost dispersion.*
Proof: By substituting (31) into (22), we get the average industry markup

$$\bar{\mu} = \int_0^{c_D} \mu(c)dG(c)/G(c_D) = \frac{1}{2}\frac{1}{k-1} \quad (33)$$

which increases when k falls and the dispersion of the marginal cost increases.[16] Q.E.D.

Why does k, reflecting the marginal cost dispersion, determine average industry markups? A firm's markup depends on its cost advantage relative to the firm with the

[15] The Pareto distribution also encompasses the uniform distribution when $k = 1$.
[16] This is also true for the revenue-weighted markup

$$\bar{\mu}_w = \int_0^{c_D} r(c)\mu_2(c)dG(c)/\int_0^{c_D} r(c)dG(c) = \frac{1}{2}\frac{2k+1}{k^2-1}. \quad (34)$$

cost c_D. With a Pareto distribution, the fraction of firms having a certain cost advantage is fixed and determined by k. A lower k implies a greater expected distance from the cutoff cost c_D which results in a higher average markup.

Interestingly, the industry markup does not depend on the cutoff cost c_D and thus, not on the level of the fixed cost f of intangible capital. To understand this result, consider the case when f and c_D increase from (29). Firms that were already productive enough to survive given the initial c_D can now charge higher markups but a mass of less productive firms charging relatively low markups will survive. With a Pareto distribution, the net effect of these two forces exactly cancel out and the average markup is unaffected. According to Autor et al. (2020), the Pareto distribution of firm productivity is log-linear in $\log(c_D)$, which implies that a change in c_D will leave the average industry markups unaffected.

A.2 The importance of intangible capital and factor shares

A.2.1 Pareto distribution

Although average industry markups do not depend on the level of the fixed cost of investment in intangible capital, f, paid by an individual firm, there is still a relationship between intangible capital and the ratio of aggregate fixed costs to variable costs in the industry.

Proposition 3 *When firm marginal costs follow an inverse Pareto distribution, there will be a higher ratio of fixed costs to variable cost in industries with a greater cost dispersion.*

Proof: We know from (28) that the total fixed cost is equal to the total operating profit in the industry. Hence, the total fixed cost to the total variable cost

$$\frac{N_E f}{N\int_0^{c_D} q(c)c dG(c)/G(c_D)} = \frac{N\int_0^{c_D} \pi dG(c)/G(c_D)}{N\int_0^{c_D} qc dG(c)/G(c_D)} = \frac{1}{k} \tag{35}$$

is also only determined by k and this ratio increases when k falls. Q.E.D.

The intuition behind this result is that when k falls and the dispersion increases, there is an increase in the markups and profits of surviving firms which attracts more firms to invest in the industry. However, firms that survive in this environment are very productive, requiring relatively little variable inputs to produce output. This results in a high fraction of fixed costs paid in proportion to the variable costs paid considering all firms that invest in the industry.

It follows from (35) that the fraction of income paid as compensation to variable production factors is lower in industries with a greater cost dispersion. Assuming that variable production factors mainly consist of labor, the fraction of income paid to labor will be lower. Another way of seeing this relationship is that high markups over variable costs among surviving firms translate into high operational profits paid to capital owners. This reasoning results in the following proposition:

Proposition 4: *When firm marginal costs follow an inverse Pareto distribution, the labor share will be lower in industries with a greater cost dispersion.*

Do higher average markups in industries with greater cost dispersion result in higher economic profits? The average operating profit share of revenue among producing firms

$$s_\pi = \frac{\int_0^{c_D} \pi(c) dG(c)/G(c_D)}{\int_0^{c_D} p(c)q(c) dG(c)/G(c_D)} = \frac{1}{k+1} \tag{36}$$

is positive and increases with a higher cost dispersion. However, to assess the presence of economic profit, we need to consider the revenue relative to the opportunity cost. When investment is risky, it is misleading to only examine the firms that succeed and end up producing in equilibrium. Instead, it is relevant to compare the total revenue to total costs of all firms that invest in the industry, including those that fail.[17] It follows from (28) that the aggregate operational profit is equal to the aggregate fixed cost. Hence, the total industry profit, that is the operational profits net of the fixed costs

$$N \int_0^{c_D} \pi(c) dG(c)/G(c_D) - N_E f = 0, \tag{37}$$

is zero in the industry as a whole. This reasoning results in the following proposition:

Proposition 5. *A higher fixed cost f or a greater cost dispersion are not associated with any economic profit.*

In fact, this result follows by construction from the assumption of free entry into the industry.

B Measuring intangible capital

B.1 Intangible capital in the national accounts

The national accounts principle is that expenditures that are expected to yield an income at least one year into the future are counted as an investment. The survey on R&D expenditure takes place every other year. Since 1995 it covers all sectors of the econ-

[17] See Carlton et al. (1990) for a discussion.

omy and since 2005 all firms with more than ten employees are included in the survey population. Firms that have more than 200 employees or firms that are R&D-intensive are asked to answer the survey each time. Among other firms, a sample is collected. In total, 7705 firms were sampled for the survey in 2015. The survey provides information on both in-house and outsourced R&D activities. In addition to spending money on developing intangible capital, firms can also acquire R&D assets, such as patents, on the market. Information on acquired R&D capital is mainly derived as a residual item based on surveys of large firms.

The survey on software spending takes place every year starting in 2005. It includes acquired software such as purchased standard programs, licenses, cloud services as well as the development of customized software solutions. However, it does not include expenditure on developing software in-house. Firms with more than 250 employees are asked to answer the survey each year whereas a sample is collected among firms with between 10 and 249 employees. In total, 4495 firms were sampled for the survey in 2015. Information on internally developed software is based on the number of workers in IT-occupations multiplied by the average wage and an estimated fraction of time allocated to own-account software development. The measurement on investment in artistic originals is based on royalty income. For all capital, adjustments are made to arrive at a market value equivalent.

B.2 Intangible capital in firm accounting

The treatment of intangible capital in corporate accounting varies across countries and time. For example, in the US, firms are allowed to recognize acquired but not internally developed intangible capital on their balance sheet. In Sweden, firms have the option, but not the obligation, to treat expenditure on internally developed intangibles as capital investment. However, small firms that have opted for a simplified accounting framework do not have the right to recognize internally developed intangible capital.[18] Moreover, at the time of a business combination, firms have significant freedom in whether to account for acquired intangible capital as goodwill or whether to identify specific intangible assets. In 2008, the 259 major publicliy listed Swedish firms reported SEK 613 billion in goodwill and SEK 334 billion in other intangible capital (Gauffin and Thörnsten, 2010). There can be strategic advantages from accounting for acquired intangible capital as goodwill rather than recognizing specific underlying assets. Primarily, goodwill is not subject to continuous depreciation but should undergo yearly impairment tests. Swedish

[18] The simplified framework K2 came into place in 2008.

firms perform little write-down of the value of goodwill, even in the period after the global financial crisis (Gauffin and Thörnsten (2010)).

The main principle behind the recognition of intangible capital other than goodwill is that it should be valued at historical cost and subject to yearly depreciation. However, the degrees of freedom in the framework imply that firms can account for expenditure on intangibles according to their strategic objectives. For example, start-up firms that have large expenditures on intangible assets but low sales have an interest in bolstering profits and equity values by reporting expenditures on intangible capital as an investment. However, profitable firms that want to reduce taxes may have an interest in reporting expenditure on intangible capital as a cost.

B.3 Comparison between intangible capital measures

Table B.1 shows a comparison between intangible capital at the industry level in the national accounts and intangible capital at the industry level derived from firm accounting data. We see that for the median industry observation, intangible capital according to the firm accounting rules is only one-fifth of the median observation in the national accounts. Moreover, the median intangible capital-intensity is only 0.04 as compared to 0.20 in the national accounts. This is likely due to the fact that many firms choose to account for expenditure on intangible assets as a cost rather than capitalizing it on their balance sheet.

Table B.1: Intangible capital in the national accounts and firm accounting

	p1	median	p99	mean	st.dev.	No.
National accounts IC	78	3,767	1.7e+05	11622	26052	965
Firm accounting IC	0	724.44	21678	2,666	7,716	1,062
National accounts IC/wL	.00905	.2032	11.252	.58882	1.4798	965
Firm accounting IC/wL	0	.04487	.95768	.11379	.20643	1,020

Notes: Intangible capital in firm financial statements summed to the same industry level as in intangible capital in the national accounts (2-digit level with some exceptions). Panel data of industry observations 1997-2016.

C Empirical model

The production function for firm i at time t is

$$Y_{it} = min[e^{\beta_0} K_{it}^{\beta_1} L_{it}^{\beta_2} e^{\omega_{it}}, \beta_3 M_{it}] \tag{38}$$

where Y_{it} corresponds to gross output, L_{it} is labor input, K_{it} is a measure of (physical) capital inputs, M_{it} is intermediate inputs and ω_{it} is firm-specific productivity.

In order to produce, firms need to pay a fixed cost f for intangible capital. f can either be paid once as in the theoretical model in Section 2 or more frequently as firms need to make investments in intangible capital to develop new products and services.

The firm's problem is to minimize its costs given a target production level Y_{it} and can be expressed as

$$\begin{aligned}\mathcal{L}_{it}(L_{it}, M_{it}, K_{it}, \Lambda^1_{it}, \Lambda^2_{it}) = & f + r_{it}K_{it} + w_{it}L_{it} + p^M_{it}M_{it} \\ & - \Lambda^1_{it}(e^{\beta_0}K^{\beta_1}_{it}L^{\beta_2}_{it}e^{\omega}_{it} - Y_{it}) \\ & - \Lambda^2_{it}(\beta_3 M_{it} - Y_{it})\end{aligned} \tag{39}$$

where r_{it} is the rental rate of capital, p^M_{it} is the price of intermediate inputs and Λ^1_{it} and Λ^2_{it} are the Lagrange multipliers. The first-order conditions with respect to labor and the intermediate inputs are

$$w_{it} = \Lambda^1_{it}\beta_2\frac{Y_{it}}{L_{it}} \tag{40}$$

and

$$p^M_{it} = \Lambda^2_{it}\beta_3. \tag{41}$$

The marginal cost of production is given by

$$MC_{it} = \Lambda^1_{it} + \Lambda^2_{it} = \frac{w_{it}L_{it}}{\beta_2 Y_{it}} + \frac{p^M_{it}}{\beta_3} \tag{42}$$

where

$$\beta_3 = \frac{Y_{it}}{M_{it}}. \tag{43}$$

which implies

$$\Lambda^1_{it} + \Lambda^2_{it} = \frac{w_{it}L_{it}}{\beta_2 Y_{it}} + \frac{p^M_{it}M_{it}}{Y_{it}} = \frac{w_{it}L_{it} + \beta_2 p^M_{it}M_{it}}{\beta_2 Y_{it}}. \tag{44}$$

This results in the markup

$$\mu_{it} \equiv \frac{P_{it}^Y - MC_{it}}{MC_{it}} = \beta_2 \frac{P_{it}^Y Y_{it}}{w_{it}L_{it} + \beta_2 p_{it}^M M_{it}} - 1. \tag{45}$$

where gross sales, the labor cost and costs of intermediate inputs can be directly observed in the data but the output elasticity β_2 needs to be estimated.

C.1 Estimation

For each 2-digit ISIC industry, I estimate the production function in log form

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \tau_t + \omega_{it} + \epsilon_{it} \tag{46}$$

where ϵ_{it} is an unexpected productivity shock. Time fixed effects τ_t are included to account for the fact that firm productivity is growing over time. I assume that firm persistent productivity evolves according to an AR(1) process

$$\omega_{it} = \rho\omega_{it-1} + \xi_{it} \tag{47}$$

where ξ_{it} can be interpreted as the unanticipated innovation to the firm's persistent productivity in period t. I consider both labor and intermediate inputs to be flexible inputs, that is, they are chosen after the firm observes persistent productivity ω_{it}.

The estimation procedure closely follows Ackerberg et al. (2015) and relies on assumptions on the relationship between persistent productivity ω_{it} and intermediate inputs m_{it}. The necessary conditions are that ω_{it} is the only unobservable entering the firms' intermediate input demand function $m_{it} = f_t(k_{it}, l_{it}, \omega_{it})$ and that this function is strictly increasing in ω meaning that, conditional on capital and labor, more productive firms use more intermediate inputs. These two conditions allow us to invert f_t and write

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \tau_t + f_t^{-1}(k_{it}, l_{it}, m_{it}) + \epsilon_{it}. \tag{48}$$

As pointed out by Gandhi et al. (2011), the output elasticity for the flexible labor input will not be identified if labor also fulfills the two conditions above. Therefore, I assume that there are persistent unobserved wage shocks that also determine labor demand.

In a first step, expected output $E(y_{it})$ is separated from the unexpected productivity shock, ϵ_{it}. The functional form of f_t^{-1} is treated non-parametrically as a second-order polynomial of k_{it}, l_{it} and m_{it} such that

$$\begin{aligned} y_{it} &= (\beta_0 + \gamma_0) + (\beta_1 + \gamma_1)k_{it} + (\beta_2 + \gamma_2)l_{it} + \gamma_3 m_{it} \\ &\quad + \gamma_4 k_{it}^2 + \gamma_5 l_{it}^2 + \gamma_6 m_{it}^2 + \tau_t + \epsilon_{it} \\ &= \tilde{\Phi}_t(k_{it}, l_{it}, m_{it}) + \epsilon_{it}. \end{aligned} \tag{49}$$

Using OLS regression to estimate (49) we obtain an estimate of expected production $\tilde{\Phi}_t(k_{it}, l_{it}, m_{it})$. Firm-specific persistent productivity is thus given by

$$\omega_{it} = \tilde{\Phi}_t(k_{it}, l_{it}, m_{it}) - (\beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \tau_t). \tag{50}$$

In a second step, I estimate the parameters based on moment conditions on the shock to persistent productivity ξ_{it}. By assuming that capital responds with a lag to productivity shocks, we get the moment conditions

$$\begin{aligned} &E\left[\xi_{it}(\beta) \otimes \begin{pmatrix} l_{it-1} \\ k_{it} \\ \tilde{\Phi}_{t-1} \end{pmatrix}\right] = E\left[\omega_{it}(\beta) - \rho\omega_{it-1}(\beta) \otimes \begin{pmatrix} l_{it-1} \\ k_{it} \\ \tilde{\Phi}_{t-1} \end{pmatrix}\right] \\ =&E[(y_{it} - \beta_0 - \beta_1 k_{it} - \beta_2 l_{it} - \tau_t - \rho(\tilde{\Phi}_{t-1} - \beta_0 - \beta_1 k_{it-1} - \beta_2 l_{it-1} - \tau_{t-1})) \\ \otimes& \begin{pmatrix} l_{it-1} \\ k_{it} \\ \tilde{\Phi}_{t-1} \end{pmatrix}] = 0 \end{aligned} \tag{51}$$

or

$$E[\xi(\beta) \otimes \begin{pmatrix} l_{it-1} \\ k_{it} \\ \tilde{\Phi}_{t-1} \end{pmatrix}] = 0 \tag{52}$$

where, in practice, $\xi_{it}(\beta)$ is obtained by regressing productivity $\omega_{it}(\beta)$ given by (50) on its own lag $\omega_{it-1}(\beta)$ using the estimate of $\tilde{\Phi}_t(k_{it}, l_{it}, m_{it})$ from the first stage. I estimate these moment conditions by iterative GMM using the procedure of "concentrating out" parameters that depend linearly on other parameters as proposed by Ackerberg et al. (2015). To increase the probability of arriving at a global optimum, I iterate over a large number of initial parameter values in the optimization algorithm and choose the estimation which results in the lowest function value.

D Data and sample selection

D.1 Variable definitions

Firm sales: Sales net of VAT. I only consider firms with nonnegative sales. For purposes of production function estimation, sales are deflated by the GDP deflator for the respective industry.

Firm labor cost: It includes contributions to social security systems. I consider firms with nonpositive cost. For production function estimation, the labor cost is deflated by the general GDP-deflator. Deflating the labor costs by the GDP deflator is meant not to only remove changes in the labor input which are due to price inflation and not due to changes in labor productivity.

Firm physical capital: This measure includes machines and buildings (including land). I consider firms with nonnegative capital values. For production function estimation, the end of year capital stock in year t-1 is used as a measure of capital input in year t. Therefore, in practice, the data ranges from 1998 to 2016. Capital stocks are deflated by industry-specific capital deflators. Land is not deflated in the national accounts but it is deflated here since it cannot be separated from buildings.

Firm cost of intermediate inputs: Intermediate inputs correspond to the value of raw materials, merchandise and other external costs that belong to the normal operations of the firm. I consider firms with nonpositive costs of intermediate inputs. For the production function estimation, intermediate inputs are deflated by the general GDP-deflator.

Industry capital stocks: Capital stocks refer to capital stocks on January 1 each year. The capital types considered are buildings and land, machines and equipment, R&D capital and software capital.

Industry debt: The book values of debt capital at the firm level are aggregated to a measure of industry debt.

Industry equity: The book values of equity capital at the firm level are aggregated to a measure of industry equity. Equity refers to total equity that is total assets - debt.

Capital inflation rates: Capital inflation rates are obtained for each industry, capital type, and year, from the national accounts.

Depreciation rates: For each industry and capital type, I obtain estimated capital depreciation rates directly from Statistics Sweden. The depreciation rates are constant across time. The depreciation rates for intangible capital are also constant across industries. The rate is 16.5 percent for R&D capital, 40 percent for externally acquired software and 20 percent for internally developed software. Since I do not know to what extent software is internally developed in each industry I assume a common depreciation rate of 40 percent for software.

Cost of debt capital: The corporate borrowing rate refers to the average rate on all loans from monetary financial institutions to non-financial firms. It is available in the MFI statistics from Statistics Sweden.

D.2 Summary statistics firm data

[Add additional details on sample selection here.]

Table D.1: Summary statistics for firm-level panel data

	median	mean	st. dev	No.
Sales	10550	68468	863414	1060133
Labor cost	3209	14589	136738	1060133
Physical capital	580	13498	272341	1060133
Intermediate input cost	5940	49046	695339	1060133
Intangible capital	0	1746	102750	868140
Intangible capital-intensity, IC/wL	0.00	0.02	0.31	868057

Notes: Variables from firm financial statements in thousands of Swedish krona. IC/wL refers to the ratio of intangible capital to the labor cost. Panel data between 1999 and 2016.

D.3 Summary statistics industry data

[Add additional details on sample selection here.]

Table D.2: Summary statistics for industry-level panel data

	p5	median	mean	p95	st. dev	No.
Markup sales-weighted	-0.01	0.07	0.10	0.32	0.11	778
Markup cost-weighted	-0.02	0.06	0.08	0.26	0.10	778
Intangible capital-intensity, IC/wL	0.02	0.19	0.43	1.60	0.62	778
Physical capital-intensity, K/wL	0.38	1.85	5.57	16.87	13.83	778

Notes: Panel data between 1999 and 2016.

E Results

Table E.1: Regression - Cost-weighted average markups and intangible capital-intensity

	(1)	(2)	(3)	(4)
Intangible capital-intensity, IC/wL	0.0304***	0.0315***	0.0281***	0.0240**
	(0.00526)	(0.00483)	(0.00458)	(0.00889)
Physical capital-intensity, K/wL	0.00201***	0.00181***	0.00157***	-0.00395***
	(0.000237)	(0.000258)	(0.000257)	(0.000908)
Observations	778	778	778	778
R^2	0.127	0.419	0.620	0.943
year fe	yes	yes	no	no
sector trends	no	yes	no	no
sector-year fe	no	no	yes	yes
industry fe	no	no	no	yes

Notes: The dependent variable is the cost-weighted average industry markup. Coefficients refer to a one-unit increase in the explanatory variables. Industry refers to the 2-digit ISIC sector level but smaller industries are grouped together. Sector refers to the 1-digit ISIC sector level. Standard errors in parenthesis. Panel data on industries between 1999 and 2016.

Table E.2: Robustness: firm markups and intangible capital-intensity

	(1)	(2)	(3)
IC/wL	0.00842***	0.00859***	
	(0.000449)	(0.000459)	
IC/(IC+K)			-0.00228*
			(0.00107)
Observations	828071	848341	848201
R^2	0.757	0.634	0.635
industry fe	yes	yes	yes
firm fe	yes	yes	yes
sector year fe	yes	yes	yes

Notes: The results are comparable to column 4 in Table 1.
Column 1: Markup according to De Loecker and Warzynski
Column 2: Markup assuming a constant beta of 0.85

Table E.3: Robustness: industry markups and intangible capital-intensity

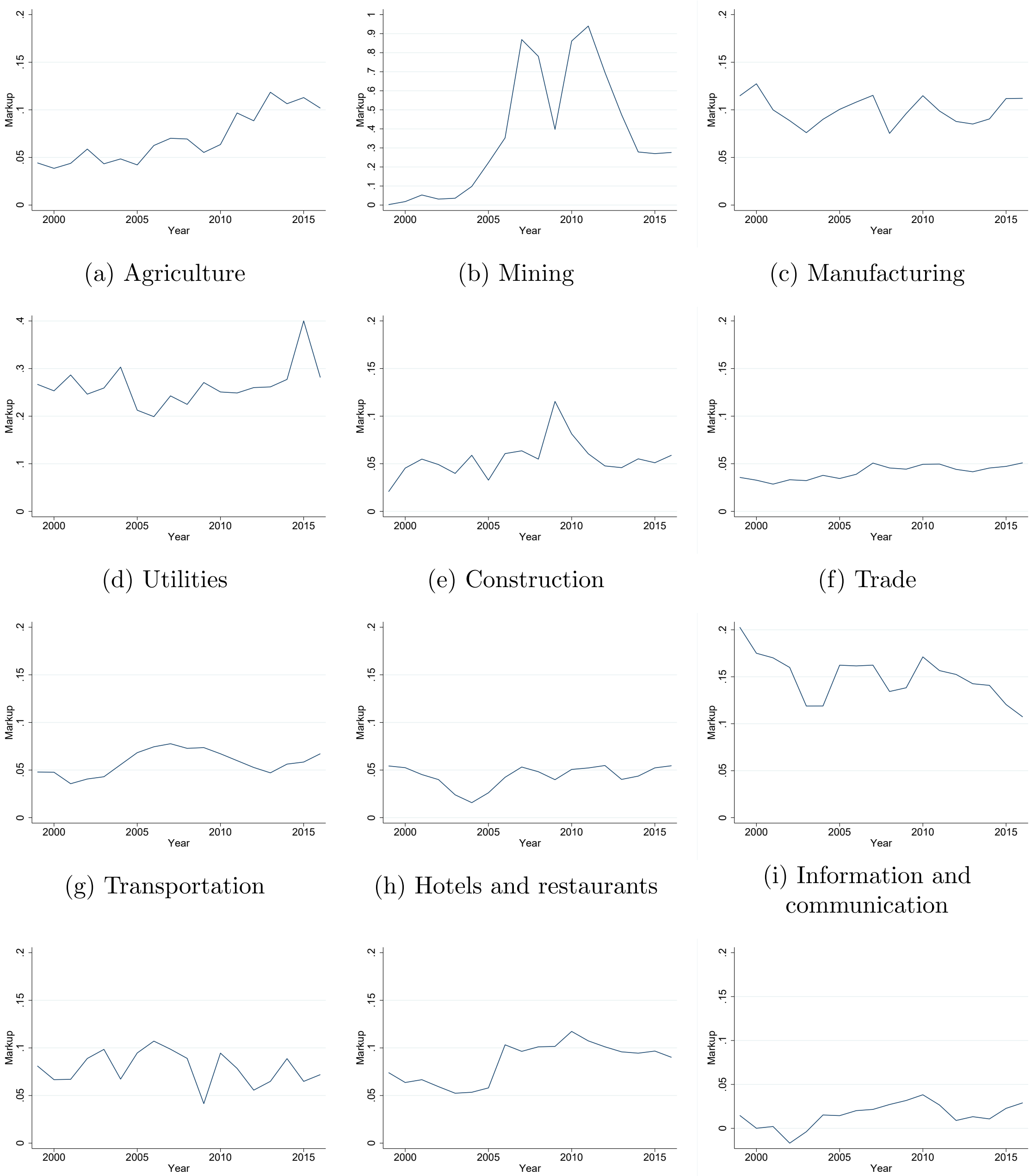
	(1)	(2)	(3)
IC/wL	0.0549***	0.0318*	
	(0.0159)	(0.0155)	
IC/(IC+K)			0.0340
			(0.0622)
Observations	743	791	778
R^2	0.994	0.897	0.940
industry fe	yes	yes	yes
sector year fe	yes	yes	yes

Notes: The results are comparable to column 4 in Table 2.
Column 1: Markup according to De Loecker and Warzynski
Column 2: Markup assuming a constant beta of 0.85

Figure E.1: Markup for 10th decile

Notes: The time series depict the weighted average markups among the top markup firms amounting to 10 percent of total sales/total cost in a given year.

Figure E.2: Markups at sector level



(a) Agriculture (b) Mining (c) Manufacturing

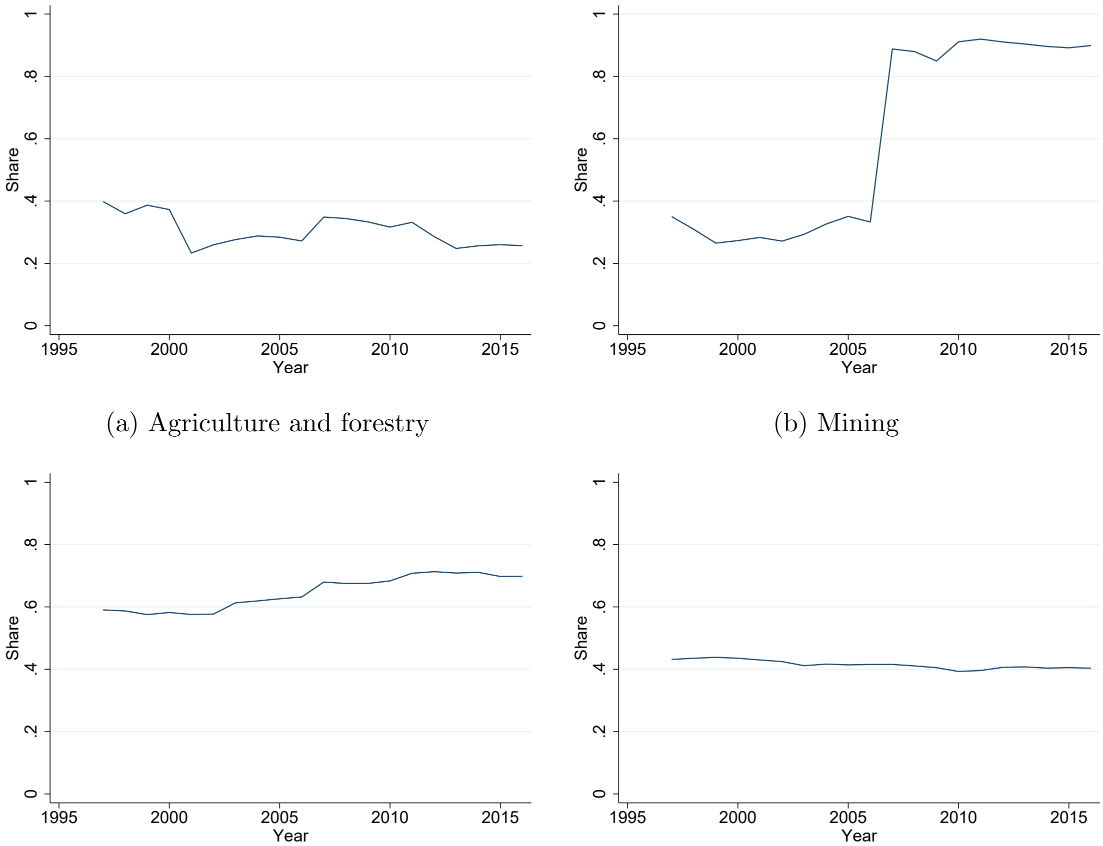
(d) Utilities (e) Construction (f) Trade

(g) Transportation (h) Hotels and restaurants (i) Information and communication

(j) Professional services (k) Other services (l) Other

Notes: Sales-weighted average markup at 1-digit ISIC/NACE sectors.

Figure E.3: Average sales concentration



(a) Agriculture and forestry

(b) Mining

(c) Manufacturing

(d) Transportation

Notes: Sales-weighted concentration at 1-digit ISIC/NACE sectors. Concentration measured as the share of the 4 firms with the largest sales in total industry sales for 4-digit ISIC/NACE industries.

F The profit share at industry level

In this section I study the correlation between measured economic profit and intangible capital in the national accounts at industry level.

F.1 Summary statistics

Table F.1 shows the distribution of industry factor shares of value added in the sample used for analysis.[19] The median labor share is 70 percent but there are observations

[19] The factor share distribution is characterized by extreme outliers in times of financial crisis and I have excluded the bottom 5 percent and top 5 percent of industry observations in terms of the labor

with a labor share above one implying that income does not cover the cost of labor. The median physical capital share is 17 percent and the median intangible capital share 4 percent of value added. Economic profit in the median Swedish industry only is 2 percent of value added but there are industry observations with significantly positive and significantly negative profits.[20] Unfortunately, missing data on capital price inflation leads to a loss of observations on the user cost of capital and capital shares.

Table F.1: Summary statistics for industry level factor shares

	p5	median	mean	p95	st.dev	No.
Labor	0.27	0.71	0.67	1.02	0.21	878
Physical capital	0.06	0.17	0.25	0.76	0.25	835
Intangible capital	0.00	0.04	0.07	0.20	0.07	800
Profit	-0.35	0.02	0.01	0.32	0.19	757

Notes: Factor shares of value added. Panel data of industry observations 1997-2016.

F.2 The profit share and intangible capital-intensity

When there is free entry into an industry, we expect zero economic profits in the long run.[21] Hence, in theory, barriers to entry is the only determinant of long-run economic profit. This means that economic profit shares are comparable across industries as long as we successfully take all factor payments into account.

Table reports the results from a regression of the profit share on intangible capital-intensity. If we think that we have measured economic profit correctly, it is relevant to study the variation across industries as reported in columns 1-3. These results in imply that an increase in intangible capital-intensity by one standard deviation (0.60) is associated with a 5 percentage point higher profit share of value added. However, it can be noted that there is not necessarily a statistically significant relationship between the profit share and intangible capital-intensity within industries over time.

If we believe that (the user cost of) intangible capital is mismeasured, there will be measurement error not only in the measure of intangible capital-intensity but also in the profit shares. For example, the National accounts measures of intangible capital do not capture all types of intangible capital and hence the user cost of intangible capital may be underreported. This would lead to an overstatement of the measured economic profit

share and profit share as well as industry observations with intangible capital-intensity above 5.

[20]It is not necessarily the same industry which represents the median of all factor shares. Therefore, the median factor shares are not summing to 1 but mean factor shares do.

[21]In the short run economic profits can be positive or negative; see Carlton et al. (1990) for a discussion.

and a positive correlation between intangible capital and measured profit. In addition, in Section F.3, I investigate the plausibility of such a scenaro. In summary, the results on the relationship between intangible capital-intensity and economic profits at industry level are not entirely conclusive.

Table F.2: Regression - Profit shares and intangible capital-intensity

	(1)	(2)	(3)	(4)
IC/wL	0.0797***	0.0778***	0.0733***	0.0486
	(0.0104)	(0.0107)	(0.0115)	(0.0305)
Constant	0.000776	-0.0590*	-0.188	-0.187
	(0.0410)	(0.0289)	(0.185)	(0.100)
Observations	757	757	757	757
R^2	0.096	0.207	0.358	0.824
year fe	yes	yes	no	no
sector trends fe	no	yes	no	no
sector-year fe	no	no	yes	yes

Notes: The dependent variable is the profit share of value added at industry level. Coefficients refer to a one-unit increase in the explanatory variables. Industry refers to the 2-digit ISIC sector level but smaller industries are grouped together. Sector refers to the 1-digit ISIC sector level. Standard errors in parenthesis. Panel data of industry observations 1997-2016.

F.3 Measurement error in the cost of intangible capital?

F.3.1 Stock of intangible capital

First, consider the case in which the rental rate of intangible capital is correctly measured, but there is measurement error in the stock of intangible capital. If the observed intangible capital is positively correlated with some unobserved capital stock, we will attribute the missing capital to higher rates of economic profit in intangibles-intensive industries. It is informative to ask what size of the unmeasured intangible capital stock that would imply a zero correlation between intangible capital and economic profit in column 1 of Table F.2. To this end, consider the equation

$$VA_{jt} - wL_{jt} - R_{Ph,jt}K_{Ph,jt} = \bar{\Pi} + R_{IC,jt}K_{IC,jt}(1+\Delta) + \Pi_{jt} \tag{53}$$

where $K_{Ph,jt}$ denotes the physical capital stock, $K_{IC,jt}$ denotes the intangible capital stock, $\bar{\Pi}$ represents average industry profit and Π_{jt} is the residual profit uncorrelated with other variables. The unmeasured capital stock is given by Δ. I normalize all variables by value added and estimate this equation in the panel of industries. The results give $\hat{\Delta}$=0.17 saying that if the intangible capital stock is on average 17 percent higher than the measured stock, there would be no positive relationship between intangible capital and economic profit. Such a difference between actual and measured intangible capital is not very large and possibly within the range of plausible measurement error. Hence, it cannot be excluded that the observed positive correlation between intangible capital-intensity and economic profit shares is due to an undermeasurement of intangible capital stocks.

F.3.2 Rental rate of capital

Second, consider the case when the intangible capital stock is correctly measured, but the rental rate of intangible capital is measured with error. For example, there are reasons to believe that the required return on intangible capital is higher than the required return on physical capital, for example since intangible capital is not collateralizable.[22] The objective is to find the average rental rate of intangible capital that is consistent with a zero correlation between economic profit and intangible capital in column 1 of Table F.2. For this purpose, consider the equation

$$VA_{jt} - wL_{jt} - R_{Ph,jt}K_{Ph,jt} = \bar{\Pi} + K_{IC,jt}R_{IC} + \Pi_{jt} \tag{54}$$

where R_{IC} is the average rental rate of intangible capital consistent with zero correlation between intangible capital and economic profit. Again, I estimate this equation in the panel of industries normalizing all variables by value added. The estimated rental rate of capital, $\hat{R}_{IC}$, is 0.28, which is almost the same as the average rental rate of capital calculated based on the formula of Hall and Jorgenson (1967) (0.29). Hence, it does not seem as if a different rental rate of capital would help explain the observed positive relationship between intangible capital and measured economic profit.

[22]See, for example, Hall (2002).