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The labor share puzzle: Empirical evidence for European countries

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ABSTRACT

Changes in labor share are documented in the literature, but its micro-sources remain unclear. At the macro level, the labor share is related to the capital-output ratio. Firm level evidence is scarce although very informative. In this paper we use microdata from European firms to study changes in labor share in 19 EU industries, over the period 2011–2019. Our results confirm that changes in firms' labor shares are related to these factors and that its decline has been accompanied by a reduction in capital accumulation, technological change and increasing markups. Further, we find heterogeneity among firms and show that the relationship between the labor share and the capital-output ratio is significantly nonlinear in many industries.

1. Introduction

The labor share measures the amount of net national income paid out in wages, including benefits and employer social contributions. In recent decades, this ratio has followed a downward trend in many economies (Blanchard et al., 1997; Bentolila and Saint-Paul, 2003; Rodriguez and Jayadev, 2010; Karabarbounis and Neiman, 2014; Dimova, 2019; Autor et al., 2020). Interestingly, real wages have grown faster than productivity in several industries and less than productivity in others. However, the aggregate labor share has declined because productivity grew faster than wages in the most productive industries, thereby shifting a growing fraction of productivity gains from labor to capital (OECD, 2012). Although debate remains regarding the extent of this phenomenon because of technical considerations such as the treatment of capital depreciation and indirect taxes (Rognlie, 2016; Bridgman, 2018; Smith et al., 2022), the apportionment of mixed income (Cette et al., 2019) and intangible capital (Koh et al., 2019), the consensus is that the fall has been significant. This is relevant for economic analysis because varying factor shares contrast with the stylized facts of Kaldor (1961) and the properties of the Cobb-Douglas production function (Bellocchi et al., 2023). Many elements of this puzzle have been put together, but the sources of this secular movement and industry-specific experiences are not yet completely clear.

The empirical literature has proposed several explanations for the aggregate decline in labor shares, most of which relate to the firm level. Focusing on firms is crucial to account for potential composition bias, as the within-industry decline may be driven by shifts of inputs and market shares towards firms with lower-than-average labor shares, rather than by within-firm changes in labor shares (Böckerman and Maliranta, 2012; Autor et al., 2020).

Recently, an emerging strand of the labor share literature, inaugurated by the seminal work of Autor et al. (2020) emphasized the role of rising concentration and markups. They found that a small fraction of "superstar firms" are responsible for the decline in labor share, highlighting a major role of structural change and the reallocation of value added among firms. However, little is known about within-firm dynamics and shocks that drive the distribution of value added at the lower levels of aggregation (Kehrig and Vincent, 2021). Yet, the most natural level of analysis to study the determinants of labor share seems to be that of firms. In fact, most of the factors discussed by the literature are specific to the production technology or firms' strategic decisions (Siegenthaler and Stucki, 2015) and the functional distribution of income is

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ultimately decided at the workplace level (Dunhaupt, 2013).

Firm level evidence is *scarce* although *very informative*. We employ data from Amadeus (Bureau van Dijk) to study the firm-level evolution of the labor share in 20 European Union (EU) countries and 19 NACE (level 1) industries from 2011 to 2019. We extend the current literature by focusing on a large group of European countries, thus contributing to a debate that has been dominated by evidence from the United States. We document several salient facts and show that the decline in the labor share is linked to the individual characteristics of firms and shows substantial heterogeneity across sectors and within firms over time.

In short, we find that the fall in labor share is related to a reduction in capital accumulation, in conjunction with increasing price markups and capital-augmenting technological progress. A one percent decrease in the capital-output ratio is related to a reduction in the labor share of the typical firm *up to* 0.85 percentage points, markups 1.08 percentage points and TFP 2.35. These results imply aggregate complementarity between capital and labor ($\sigma \approx 0.7$). In addition, we show that the relationship between the labor share (LS) and the capital-output ratio (k) is nonlinear in nature, with substantial heterogeneity across industries. Notably, in some industries the *LS-k* curve becomes non-monotonic, with a turning point coinciding with the value of k at which the elasticity of substitution crosses unity.

The paper is organized as follows. Section 2 reviews the literature. Section 3 presents some stylized facts on the evolution of labor share following a top-down approach. Then, a simple theoretical framework is presented in Section 4.1, and the resulting empirical relationships are studied and discussed in Sections 4.2, 4.3 and 4.4. Finally, Section 5 concludes the analysis with some policy implications.

2. Literature review

The functional distribution of income was defined by Ricardo as "*the principal problem of political economy*" (Ricardo, 1821). The topic was debated in the early twentieth century, as well as in the fifties and sixties (Giovannoni, 2014), when the pioneering work of Kaldor (1961) and his concept of "stylized facts" of economic growth became accepted among economists. Factor shares remained stable until forty years ago, and this constancy was considered a "*bit of a miracle*" by Keynes (1939) or "*a law*" by Bowley (Samuelson, 1964). Times of large-scale shared economic gains and prosperity shifted the focus of economists from distribution to growth. For at least twenty years, the labor share in industrialized countries remained stable throughout expansions, recessions, inflation waves, and the transition from manufacturing to service economies. However, the recent worldwide decline in labor shares, as well as rising inequalities on the personal side of the income distribution have revived this research field. Interest in the field further increased after the global financial crisis and the worldwide dissipation of wealth along with a pronounced decline in aggregate demand. If, according to Gordon (2015) the economic growth rates of the past century have stalled because their drivers have been exploited, the distribution of income will become more contested.

The existing literature has offered several explanations for the decline in labor share, including (i) rapid technological progress; (ii) the globalization of trade and capital; (iii) product and labor market institutions and market concentration; (iv) the bargaining power of labor and unemployment. There is a wide range of results on the relative importance of these factors obtained using several econometric techniques with either country-, industry-, or firm-level data (Bloise et al., 2021; Song, 2021). Firm-level studies make it possible to dig deep into the problem, but as far as European countries are concerned, difficulty in finding reliable data has limited the development of the empirical literature, which has focused mainly on the United States. *Technological progress* is presented as a factor responsible for movements in labor share, with research stressing the role of capital accumulation and capital-augmenting technological change (e.g., Bentolila and Saint-Paul, 2003; Karabarbounis and Neiman, 2014; Piketty and Zucman, 2014). Karabarbounis and Neiman (2014) have put forward the idea that embodied technological change affects factor shares through a reduction in the relative price of capital goods. This reduces the cost of capital for firms and gives them an incentive to replace one factor with another. More recently, Eden and Gaggl (2018), Acemoglu and Autor (2011) and Acemoglu and Restrepo (2018, 2020) refined this explanation by focusing on the role of ICT, artificial intelligence, and robots, respectively. Automation displaces labor demand and wages by replacing low-skilled workers in the tasks they perform. This negative outcome of technology is offset by a relative productivity effect that increases the demand for labor in non-automated activities, but is not sufficient to preserve the labor share.

A common argument of these papers is that the *elasticity of substitution* between capital and labor is greater than unity, but evidence on this fact is conflicting (Knoblach and Stöckl, 2020; Bellocchi and Travaglini, 2023). A large literature exploiting time-series and cross-firm variations for the US (Antras, 2004; Chirinko, 2008; Klump et al., 2012; Young, 2013; Oberfield and Raval, 2014; Herrendorf et al., 2015, Chirinko and Mallick, 2017) finds an elasticity of substitution between capital and labor below unity ($\sigma \approx 0.6$–0.8) and thus complementary factors of production. On the other hand, studies exploiting cross-country variations in factor shares (Karabarbounis and Neiman, 2014; Piketty, 2014; Piketty and Zucman, 2014) tend to imply substitutability, with $\sigma \approx$ 1.2–1.3.

Studies revealed negative (but small) effects of *globalization* on the labor share in developed countries (Schwellnus et al., 2019). International trade and financial integration have increased dramatically over the past forty years. These processes have been driven by the reduction of restrictions and tariffs on international trade and capital mobility, which have pushed firms towards a global reallocation of their activities. Increasing import competition has encouraged the relocation of the lower-skilled and labor-intensive stages of production to cheaper, labor-abundant countries (Dao et al., 2017). Elsby et al. (2013) advocate the role of offshoring as an important driver of the labor share decline in the US. However, recently, Autor et al. (2020) showed that the decline in labor share involved both tradable and non-tradable sectors, thus weakening this latter hypothesis.

Finally, research has addressed *institutional factors* affecting the labor share. Although technological conditions determine factor substitutability, the speed at which firms replace labor with capital depends on frictions in the labor market, which are eventually determined by the institutional setting. Labor market institutions, product market regulations and workers' bargaining power were discussed in terms of their potential influence on the labor share (Guschanski and Onaran, 2021). The decline in union density in developed economies has been linked to a reduction in the bargaining power of workers, which negatively affects their ability to negotiate a larger share of productivity gains (Young and Zuleta, 2018). Similarly, minimum wage (Harasztosi and Lindner, 2019), employment protection legislation (Ciminelli et al., 2018) and the generosity of unemployment benefits have been analyzed (Pak and Schwellnus, 2019). Blanchard and Giavazzi (2003) argue that the weakening of employment protection policies has contributed to the decline of the labor share in OECD countries. Other studies have attributed most of the decline to product market deregulation. Azmat et al. (2012) illustrated that a reduction in market competition has depressed labor shares in Europe but found no evidence of a labor market effect. Bassanini and Manfredi (2014) associate increasing market competition with increasing labor shares as falling barriers to entry reduce firms' rents. The importance of market institutions is clear, but the evidence is mixed.

The results put forward by Autor et al. (2020) indicate that increasing market concentration, favored by the use of new technologies, is one of the factors behind the decline in labor share in the United States. Similarly, Barkai (2020) and De Loecker et al. (2020) show that markups have grown in recent years and detect a negative relationship between market pricing and labor share. As such, the role of market regulation is at the fore of different explanations and deserves further investigation.

Micro-level studies provide in-depth knowledge of factors that determine the labor share. Specifically, they can account for potential composition bias *between* (De Serres et al., 2002; Arpaia et al., 2009; Young, 2013; Elsby et al., 2013) or *within sectors* (Kyyrä and Maliranta, 2008 and Böckerman and Maliranta, 2012).[1] They also make it possible to address firms' heterogeneity and focus on how firms' strategies influence the distribution of rents between capital and labor. In fact, the functional distribution of income is ultimately decided at the workplace level (Dunhaupt, 2013).

The aim of this paper is to contribute to the debate on the micro-determinants of labor share in European countries. We build on the theoretical insights of Bentolila and Saint-Paul (2003) and express the labor share as a function of a set of technological and institutional factors. We extend the current literature in several directions. First, we estimate the relationship between the labor share and the capital-output ratio within individual heterogeneous firms. This is relevant given that changes of the labor share in the EU cannot be fully explained by intra-industry restructuring (Landini et al., 2020). To this aim, we exploit the panel dimension of our data to ensure that our results are not driven by endogeneity or unobserved time-invariant attributes of firms that may be correlated with organizational decisions (Guadalupe and Wulf, 2010). This contrasts with other studies that have used European data to analyze the labor share-capital curve at the sectoral level.[2] A further element of our analysis concerns the issue of potential nonlinearity in the *LS-k* curve. Such nonlinearities may arise if the elasticity of substitution between capital and labor is correlated with the capital-labor ratio. The latter possibility, which has recently been introduced theoretically (Growiec and Mućk, 2020), has not yet been tested by any empirical study. At this purpose, we estimate the *LS-k* curve by means of the generalized method of moment (GMM) technique. Specifically, we follow the procedure developed by Kiviet (2020) to model our dynamic behavioral relationship. This allows us to include all the relevant transformed lagged regressors, as well as nonlinear terms to identify sector-specific thresholds and extract reasonably accurate inferences from our observational panel data set (Xue and Yip, 2013).[3]

3. Stylized facts

Labor shares in EU countries began a downward trend in the 1980s. They reached their lowest level in fifty years just before the financial crisis of 2008–09 and have not recovered since. During the most difficult years of the global economic crisis, the long-term downward trend stopped, to collapse again after 2009, suggesting that wages are less volatile than profits during economic recessions (Hur, 2021). The countercyclical behavior of the labor shares in advanced economies is documented in business cycle research (Schwellnus et al., 2019) and is caused by the presence of insurance mechanisms for households and firms in the wage bargaining process (Charpe et al., 2019).

At the same time, the extent of the decline in labor shares has been *heterogeneous*. The downward trend was observed both in recession-hit advanced economies like Ireland, Italy, Portugal, and Spain and in economically prosperous economies such as Austria, Belgium, and Germany. The new EU Member States from Eastern Europe such as Croatia, Hungary and Poland, also experienced a decline, and a few of them (e.g., Estonia and Bulgaria) are now on the rebound (Kónya et al., 2020). Additionally, several emerging economies have increased their labor share over the period. From a cross-country perspective, striking differences exist across countries that are similar from a technological point of view. Moreover, the labor shares of economically integrated areas do not show convergent patterns.

The (adjusted) labor share fell from an average of 60–65% of income in the most advanced countries of the EU28 and from 54 to 57% in Eastern European countries between 2000 and 2019 (Figure A1).[4] None of these countries - with exceptions of Bulgaria and Latvia - experienced an increase. The implication is that labor in these countries is obtaining an increasingly smaller share of the private sector's pre-tax revenue.

A falling labor share implies that wages are growing slower than productivity. If labor productivity increases due to technological progress, which goes hand in hand with a steady increase in labor incomes, a declining labor share is a byproduct of positive economic development (IMF, 2017). However, in several economies, the decline in the labor share occurred because real wage growth failed to keep pace with weak productivity growth (Figure A2)[5] (Bellocchi et al., 2021a, Bellocchi et al., 2021b). In these cases, the decline in labor share was accompanied by an increase in income inequality (Piketty and Zucman, 2014; Manyika et al., 2019).

The trend of stagnating or declining labor shares in the EU presents considerable heterogeneity not only between countries but also across sectors, and – notably – firms (Dimova, 2019). Several studies suggest that the trends observed in Europe could hide important composition factors (*see* De Serres et al., 2002; Arpaia et al., 2009; Dao et al., 2017 and Dimova, 2019).[6] Since the early 1990s, several industries characterized by low labor shares - in particular services such as financial intermediation, insurance, and real estate - have gained importance in most EU countries. At the same time, traditionally labor-intensive industries, such as manufacturing subsectors like textiles and leather, have shrunk, thus depressing the aggregate labor share. In Fig. 1, we use Eurostat data to break down aggregate changes in labor share into *within-sector* and *industrial composition* effects by means of a standard shift-share analysis for the period from 1995–2019.[7]

The evolution of the *within-industry* labor share replicates closely the evolution of the observed (aggregate) labor share, suggesting that the *between-industry* component - which captures structural change - is

[1] A firm-level analysis allows us to overcome several measurement issues concerning the accounting of employment and self-employment incomes in labor share (Glyn, 2009; D'Elia and Gabriele, 2019).

[2] Some exceptions for individual countries are Adrjan (2018) which uses UK firm-level data and found that firms with greater market power and a higher capital-to-labor ratio allocate a smaller proportion of their value added to workers. Bauer and Boussard (2020) who documented that the reallocation of value added contributed negatively, and firm level markups contributed positively to the decline of the labor share in France. Dall'Aglio et al. (2015) which found a key role of the capital-output ratio in affecting the Italian labor share in the medium term.

[3] We thank an anonymous referee who guided us in this direction.

[4] The main tables and figures of our analysis are shown in the paper. Additional tables and figures are available in the Online Appendix and referred to with the prefix "A".

[5] On the links between real wages and labor productivity, *see* Mendieta-Muñoz et al. (2020). For the productivity slowdown, Saltari and Travaglini (2009), Ollivaud et al. (2016) and Giombini et al. (2017).

[6] De Serres et al. (2002) found that from the 1970 to the 1990s most of the variation in the labor shares of France, Italy and the US was related to the *within-sector component*, while in Germany the downward trend was explained mainly by a *compositional shift*. Garrido Ruiz (2005) and Arpaia et al. (2009) confirm this result for Spain and the EU.

[7] Results for individual countries are shown in Table A1 (Online Appendix A). For further details on the methodology employed refer instead to the Online Appendix B (i - Derivation of the formulas employed in the shift-share analysis). In Figures A3 and A4, we perform the same decomposition exercise for the period 2011–2019 with microdata from Amadeus (Bureau van Dijk).

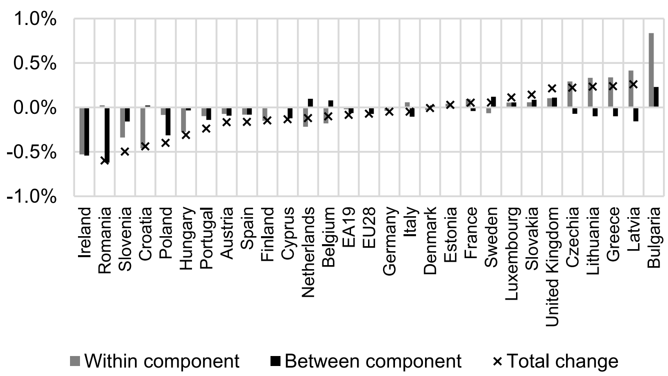

Fig. 1. Within and between-industry changes in the business sector's labor share, 1995–2019.
Note. Shift-share decomposition of variations in the labor share of the whole economy, partitioned in 11 NACE industry. Average annual contribution of each component (in % points). Source: Authors' calculation on Amadeus.

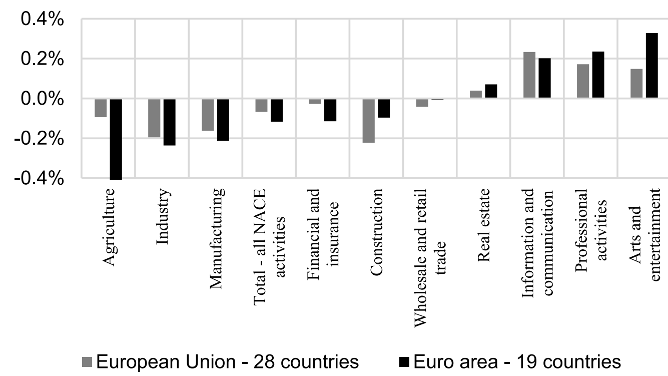

Fig. 2. - Cross-country average of within-industry changes in the labor share, 1995–2019. Note. Average of within-industry annual percentage-point variations. The order of industries is increasing with respect to the annual percentage change in the labor share (EU28). Source: Authors' calculations on Amadeus.

relatively unimportant in explaining the evolution of the labor share in Europe.[8] In fact, more than 70% of variation in labor share trends across countries is explained by within sector (one digit) variations (Figure A5). Notably, the role of inter-sectoral reallocation is small (on average) but plays a dominant role in Romania, Ireland and Poland, where structural change accounted for a decrease in the aggregate labor share of more than 0.15 p. p. Per year. In contrast, in several countries (notably Belgium and Sweden), the reallocation of value added to high-wage-share industries limited the aggregate consequences of sizeable within-industry falls in the labor share. Finally, in all other countries that experienced a reduction in the labor share, the reallocation of value added across industries played only a minor role. In the few cases where this happened, most of the reallocation took place from agriculture, manufacturing, accommodation and other services to construction, transportation and professional activities. These results can be explained by the stable industrial structure of developed economies and a reallocation of resources among high labor share sectors.[9]

A key question is whether the decline in labor share has been homogeneous across sectors or whether it has been more significant within specific industries. Fig. 2 shows that on average across EU28 countries, the *within-industry* component of the labor share declined or remained stable in all business sectors, with the only exceptions of professional and technical activities; information and communication; arts and entertainment (where the labor shares rose by 0.54% per year).

However, these sectors together account for less than 35% of the total value added generated in the EU28 and hence are not sufficient to stop a fall at the aggregate level. Conversely, large contractions in the labor share (above 0.34% per year on average in the EU28) occurred in the construction and high-tech manufacturing industries, while declines were minimal in other service activities and low-tech manufacturing.

We conclude our review of stylized facts with a breakdown of *between- and within-firm* changes in labor share. To this end, we employ micro data from Amadeus to explore the role of between-firm reallocation of value added in falling labor shares.

As shown in Fig. 3, in eleven of the nineteen industries considered, we observe a decline in the aggregate labor share between 2011 and 2019. We find that the decrease in the unweighted average labor share among firms has been limited in most economic sectors (Fig. 3 - *panel B*). However, the typical firm shows a modest decline in its labor share. In addition, while results reported in the main text are derived from a standard Olley and Pakes (1996) decomposition where the internal component is simply the unweighted average of within-firm variation, they are robust to alternative decomposition techniques (Figure A9). This suggests that the observed within-firm changes in labor share is not influenced by the contribution of large firms.[10]

All EU28 economies experienced a decline in labor share and an increase in market concentration (measured through an increase in markups), with the decline in labor share greater in those sectors where concentration increased the most (Fig. 3 - *panel C*). This result is in line with those of Autor et al. (2020) and Kehrig and Vincent (2021), who analyzed changes in the labor share in the US. Like us, they find that the reallocation term dominates accounting exercises of this type.

However, in contrast to the results for the US, in the case of EU countries, the *within-firm* component is *not negligible*. Indeed, it accounts for 30% of the observed decline and remains important in several sectors, including: mining; professional activities; electricity and gas; water supply and waste management. According to our calculations, the *within-firm decline* contributed significantly to the aggregate decline in labor share in twelve of the nineteen industries analyzed. This corroborates the findings of Landini et al. (2020) which show that the reallocation of resources from high and mid labor share firms to low labor share firms played a minor role in explaining *within-industry changes* in labor shares in European countries.

Therefore, neither market dynamics nor labor share dynamics at the

[8] These results are robust to the exclusion of industries for which the labor share is estimated with high uncertainty: (i) real-estate, whose VA is reported as capital income since results from the imputation of owner-occupied housing; and (ii) public administration and social services, which are provided by the public sector and whose VA is equal to the sum of labor costs. Moreover, we reach the same conclusion for the Euro Area (EA) (Figure A8).

[9] As expected, the correlation between the various components of the shift-share obtained with macro data for the periods 1995–2019 and 2011–2019 (Figure A6) shows a loss of correlation of the between-effects as the period of analysis is shortened. This means that over a shorter time period, structural dynamics become less important in explaining aggregate changes in the labor share. At the same time, however, the strong correlation between the within components over the two time periods indicates that intra-sector trends in labor shares are still in place in the most recent years. Finally, the micro-macro correlation for 2011–2019 (Figure A7) points to a good "matching" between national account and firm-level data to capture labor share trends over the period analyzed.

[10] The entry/exit of firms in the panel could influence the sectoral downward trend if the labor share of the typical firm leaving is higher than the average, while that of the typical firm entering is lower. To assess the importance of entry and exit, we compute the labor share for a strongly balanced sample of firms that were permanently active from 2011 to 2019. If entry and exit were the primary drivers of the labor share decline, the labor share in this strongly balanced sample should be stagnant. However, the labor share trends in the sample of long-lived firms are very similar to those in the strongly balanced sample. The results of this additional analysis are reported in the Online Appendix C. We thank an anonymous reviewer for pointing this out.

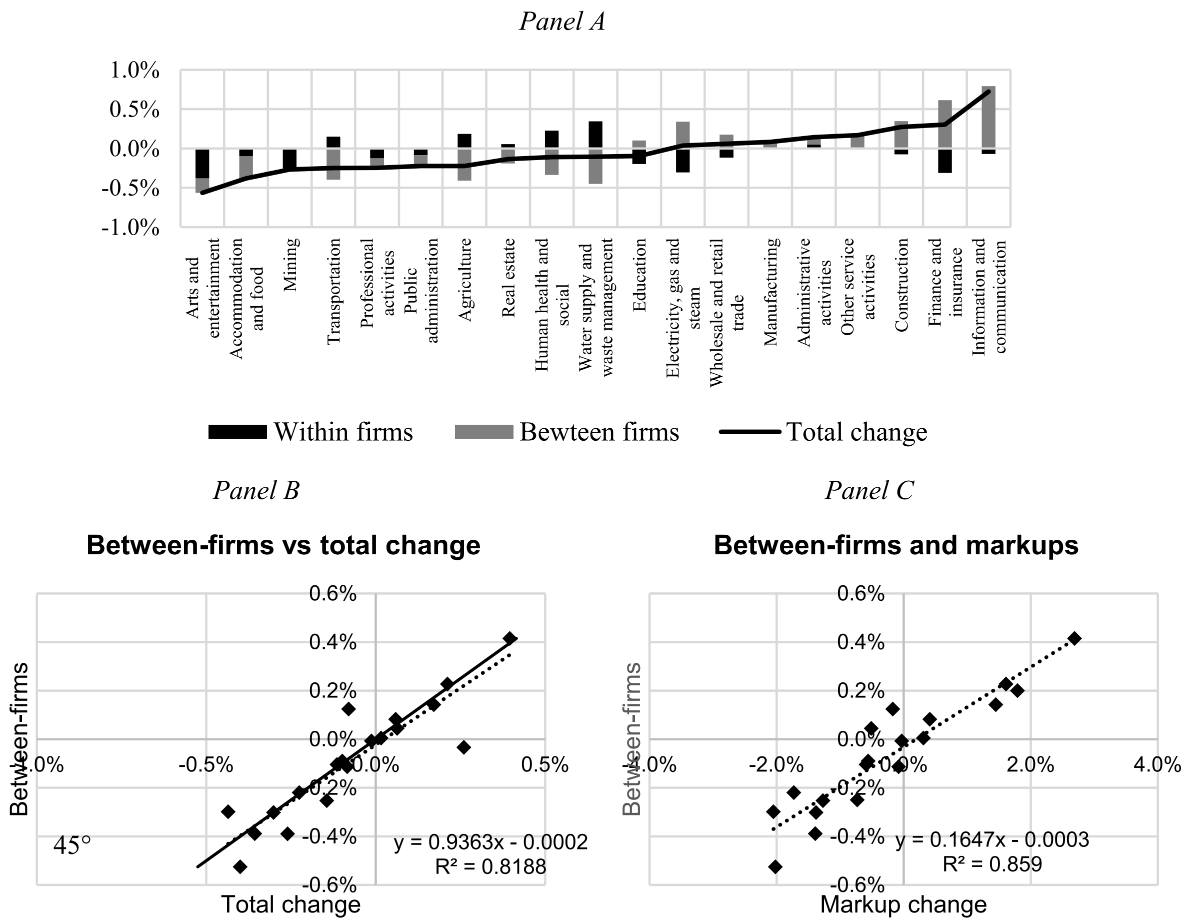

Fig. 3. Within and between-firms decomposition of business sector's labor share, 2011–2019. Note. Shift-share decomposition (Olley-Pakes) of changes in the labor share for the whole economy, partitioned in 19 industries. Between-firm refers to the reallocation component occurring between incumbent firms, while within-firm refers to the unweighted average change in the labor share. The black overpressure line in Panel B represents the 45° line. Source: Authors' calculation on Amadeus data.

firm level can, on their own and separately, explain the *within-industry* development of the labor share in the EU. Instead, the joint dynamics of labor shares at the micro level and changes in market shares are key to our understanding of aggregate trends in labor share. In the next sections we study with an *empirical approach* the traditional variables identified in the literature as determinants of the labor share *within* individual (heterogeneous) firms.

4. Empirical analysis

4.1. The model

The analysis of the labor share is conducted in the spirit of Bentolila and Saint-Paul (2003). The labor share in value added of firm *i* is defined as $LS_i = W_i L_i / P_i Y_i$, where W_i is the nominal average compensation for one unit of labor L_i in firm *i*, and $P_i Y_i$ is the value added in monetary terms. Under the assumption of constant returns to scale (*CRS*), competitive markets, and labor-augmenting technological progress – i.e. $Y_i = F(K_i, B_i L_i)$ - there is a one-to-one relationship between LS_i and the capital-output ratio ($k_i = K_i / Y_i$). This is the so-called *LS-k* curve (or "*share-capital schedule*"):

$$LS_i = f(k_i) \tag{1}$$

Thus, there is a unique function $f(\bullet)$ to explain the LS_i of a firm based on its capital-output ratio, which in turn depends on factor prices and labor-augmenting technological progress. This implies that variations in labor share across countries, sectors and firms are related to different values of capital-output ratios and different elasticities of substitution between factors. The response of the labor share to the capital-output ratio depends on the *elasticity of substitution* between capital and labor (indicated by σ) and the elasticity of labor demand to wages (η):

$$\frac{dLS_i}{dk_i} = \frac{\mathrm{dlog}(\mathrm{K}_i/\mathrm{L}_i)}{\mathrm{dlog}(\mathrm{r}_i/\mathrm{w}_i)} = -\left(\frac{1+\sigma_i}{k_i \eta_i}\right) \tag{2}$$

As k_i is positive and the elasticity of demand for labor with respect to wage is negative, a positive slope of the schedule (i.e., a positive coefficient in the regression of LS_i on k_i) means that the absolute value of the elasticity of substitution between factors $|\sigma_i|$ is lower than one (factor complementarity). On the other hand, for $|\sigma_i| \geq 1$, firms substitute capital for labor, and the *LS* curve in the (k, LS) plane slopes downward. These two cases refer to the Constant Elasticity of Substitution (CES) production function, where the elasticity is constant and factor shares are isoelastic. On the other hand, when $\sigma_i = -1$ (i.e., Cobb-Douglas case), changes in relative factor intensities are offset by changes in relative prices, and the labor share is independent of the capital-output ratio. However, as argued by Bentolila and Saint-Paul (2003): "*For more general production functions, the relationship need not be monotonic, so that the labor share can go up and then down as some variable driving changes in* $\mathrm{k_i}$ *varies.*"

Many models of income distribution have been developed with the help of a production function subject to certain restrictive features. For a long time, the Cobb-Douglas production function (CD) provided a simple framework with its input exponents adding up to unity and a unitary elasticity of substitution. But the discovery of more representative production functions has resulted in a greater accumulation of information on income distribution. The most popular production function is the CES, which includes the CD as a special case. Nevertheless, the substitution parameter in this production function is fixed, though it can take different values for different industries, thus implying a linear *LS-k* curve. Production functions with variable elasticity of substitution (VES) or isoelastic elasticity of substitution (IIES) overcome this shortcoming, as they explicitly permit the capital-labor ratio to be an explanatory variable of productivity (Kazi, 1980). In light of this, the structural extent of σ becomes much more relevant and can shed further light on the allocation of resources within sectors and firms.

The empirical identification of σ is a notoriously difficult task. Looking at the literature on the elasticity of substitution between capital and labor, we observe substantial cross-country heterogeneity (Mućk et al., 2018). Nevertheless, caveats already apply when looking at US data alone. Growiec and Mućk (2020) have estimated the elasticity of substitution under a normalized CES specification in rolling windows, obtaining clear evidence of a downward trend in the value of this parameter over time. Their results indicate that while capital and labor were gross complements in the US, the degree of mutual complementarity increased. To the extent that this is true, the relationship between the labor share and the capital-output ratio may be *nonlinear*.

The *LS-k* curve is a technological relationship, and hence it is more appropriate to investigate it at the firm rather than at the industry level. A key point for the validity of the empirical analysis is to ensure that the estimated relationship is stable. According to Bentolila and Saint-Paul (2003) shifts in the *LS-k* schedule have *two main causes*. The first concerns change in the characteristics of the production function which are not of the labor-augmenting type. This for instance is the case of capital-augmenting technical progress. The second cause includes the set of possible deviations from the competitive market hypothesis.

We proxy capital-augmenting technological progress by the *firm-level TFP*, A_{it}. Market competition, instead, is proxied by the *firm-level markup*, μ_{it}.[11] Notably, we do not restrict the functional form of the labor share to the one derived for a specific production function, and start from a general form representing an augmented *LS-k* curve:

$$LS_{it} = f(k_{it}, A_{it}, \mu_{it}) \tag{4}$$

Specifically, we take the log of (4) and estimate the following dynamic linear model[12]

$$\log LS_{i,t} = \alpha_i + \sum_{l=1}^{3} \lambda_l \log LS_{i,t-l} + \sum_{l=0}^{3} \beta_l \log k_{i,t-l} + \sum_{l=0}^{3} \gamma_l \log TFP_{i,t-l} + \sum_{l=0}^{3} \delta_l \log \mu_{i,t-l} + + \sum_{s=2}^{T} \tau_s d_{i,t}^{(s)} + \eta_i + \varepsilon_{it} \tag{5}$$

where $i = 1, \ldots, N$ and $t = 1, \ldots, T$. The labor share of firm i at time t, $LS_{i,t}$ is explained by: (i) (up to) three lags of the dependent variable, to account for persistency and dynamic adjustments; (ii) three lags of three distinct explanatory variables: $k_{i,t}$, $TFP_{i,t}$, $\mu_{i,t}$; (iii) $T-1$ time-dummies, where $d_{i,t}^{(s)} = 1$ for $t = s$ and zero otherwise; (iv) N random or fixed individual effects η_i; and (v) idiosyncratic disturbances ε_{it}. Notably, the inclusion of firm fixed effects is meant to account in a flexible way for all time-invariant firm-specific unobservables (including e.g., management quality, firm-specific advantages, etc.). Equation (5) is estimated using our unbalanced panel of 716,028 firms belonging to 19 1-digit NACE rev. 2 sectors from 20 EU28 countries for the period from 2011 to 2019. Empirically, its coefficients can be identified by rewriting a dynamic version of the labor share equation in (4). However, as pointed out in the literature, some of the explanatory variables may be endogenous to the labor share (Acemoglu, 2003). In addition, the FE estimator may be biased when the lagged dependent variable is included in the model (Nickell, 1981; Baltagi, 2021). Therefore, to address both endogeneity and specification-related problems, we rely on the *first difference GMM estimator* (Arellano and Bond, 1991). As instruments, we employ the second/third lag of the labor share and the first lag of $k_{i,t}$, $TFP_{i,t}$ and $\mu_{i,t}$, which are the latest valid instruments under the assumptions of the model. The GMM will form our *baseline model*.

To find a suitable specification and a good set of instrumental variables to draw reasonably unbiased estimates from our panel data set about the identified behavioral structural dynamic relationship, we follow the procedure proposed by Kiviet (2020). The latter pursues three main objectives: (i) include all the relevant lagged regressors; (ii) correctly identify which internal variables could represent valid instruments; (iii) enhance the accuracy of inference by omitting redundant regressors.

The procedure is composed of *two stages*. The first stage is an *inductive bottom-up discovery* phase to search for an acceptable maintained statistical model. The latter should reveal patterns of serial correlation in the disturbances and possible invalidity of subsets of instruments. Next, with a *top-down deductive specialization* phase we impose extra coefficient restrictions and exploit extra moment conditions. This aims at discovering redundant or omitted regressors, and additional valid instruments to improve efficiency. In our final configuration, we include up to three lags for the dependent and each independent variable and consider the variables to be *endogenous* or *predetermined* (as suggested by the incremental Hansen test) (Tables A3 and A4).[13] All sequential steps to get to our final configuration are explained in detail in the Online Appendix B. As stressed by Kiviet (2020), a crucial issue concerns what transformation of the variables realizes that the coefficient of each regressor in the estimated model will be constant in the sample and over the whole population. To account for potential nonlinearities in the relationship between the capital-output ratio and the labor share we consider a *third-order polynomial*, as this allows for either linear, U-shaped and S- or N-shaped relationships.[14]

4.2. Descriptive evidence

We consider the factors determining the evolution of the labor share at the firm level in 20 EU-28 countries and 19 sectors over the period from 2011 to 2019. We use balance sheet and income statement data from Amadeus (Bureau van Dijk) for 716,028 firms. Online Appendix C provides further details on the database, variables, data construction, the number of unique firms and the number of observations. The covered firms in these 19 one-digit sectors (NACE rev. 2) comprise approximately 65%–85% of both total employment and value added in

[11] Markups and TFPs are estimated using the *generalized cost-minimizing producers procedure* and a *translog production function* following De Loecker and Warzynski (2012) (*see* the Online Appendix B (ii) - Markup and (iii) - TFP for more details on the procedure employed).

[12] Note that equation (4) is a general function. To express the labor share in log-linear form as in the empirical analysis, we assume a multiplicative form (Bentolila and Saint-Paul, 2003; Parisi, 2017; Young and Zuleta, 2018; Fukao and Perugini, 2021). The choice of a general multiplicative function is a flexible way of not limiting the functional form of the labor share to one derived from a specific production function. It assumes a certain data structure but remains flexible enough to adapt to several production functions.

[13] Given the characteristics of our panel, we model (in accordance with *Hansen's over-identification test*) the capital stock and the TFP as determined by past investments, managerial practices and other factors that affect the firm's overall production function but are not directly influenced by the level of labor input *in the short run* (Gopinath, 2015).

[14] In our search for a suitable specification, we also considered interaction terms between variables to account for non-constant partial derivatives. The results of these estimates, however, end up being very difficult to interpret as they require the estimation of marginal effects for a wide combination of values of the independent variables. Therefore, although we decided not to report them in the paper, we leave them available upon request to the authors.

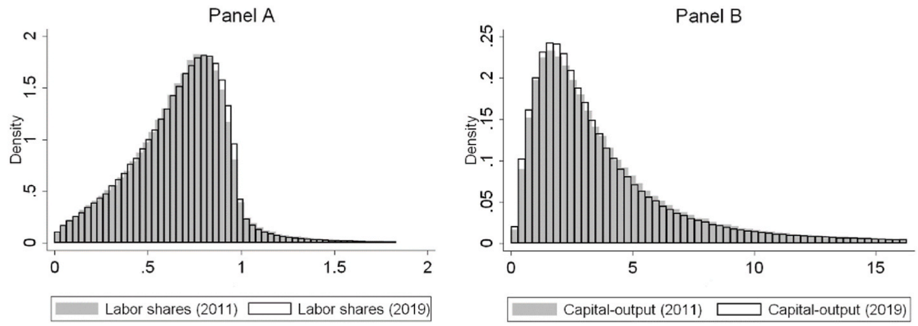

Fig. 4. Distribution of firms' labor shares and capital-output ratios, 2011 and 2019. Note. The grey area reflects the weighted raw distribution of firms' labor shares (panel A) and capital-output ratios (panel B) in 2011, while the black overlapping outline that in 2019. Source: Authors' elaboration on Amadeus data.

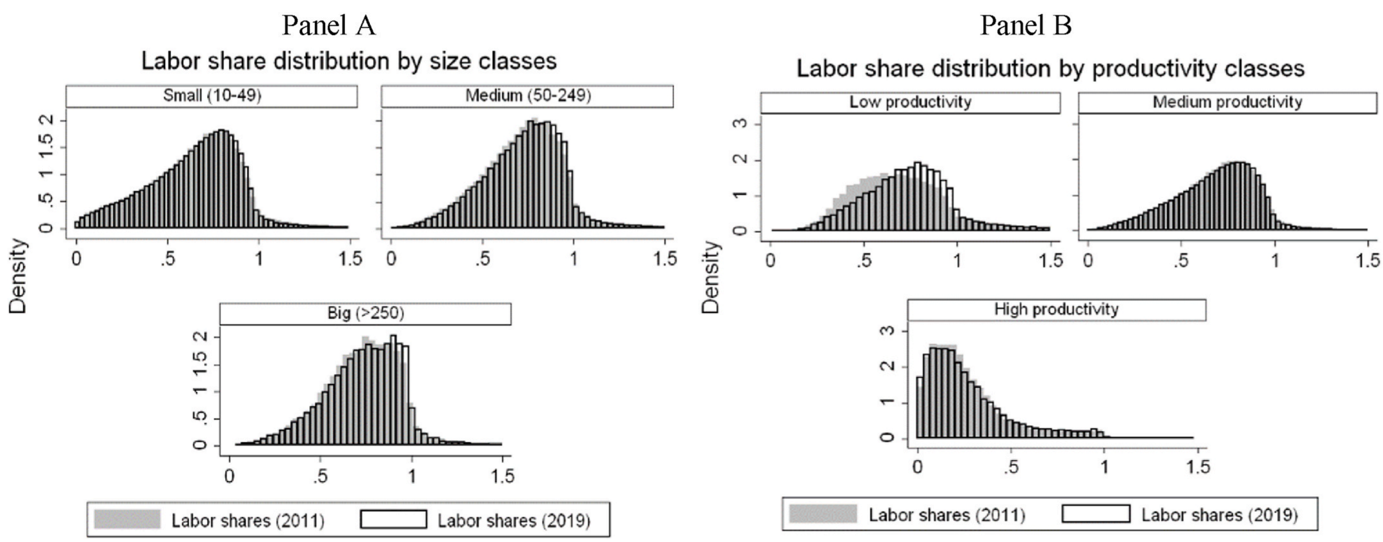

Fig. 5. The changing distribution of firms' labor shares by size and productivity classes, 2011 and 2019. Note. We consider as high-productive firms those that belong to the highest decile of the distribution of labor productivity, while low-productive firms are those in the lowest decile. The grey area reflects the weighted raw distribution of labor shares in 2011, while the black overlapping outline that in 2019. Source: Authors' elaboration on Amadeus data.

the selected countries.[15] Total labor compensation in Amadeus includes all forms of paid compensation, such as wages and salaries, paid in cash or in kind as well as employer contributions to pensions, healthcare, and social insurance. The gross value added is estimated as sales minus the cost of intermediate inputs. Finally, the capital stock is calculated as the book value of tangible and intangible assets. All the monetary variables are deflated by means of sector- and variable-specific deflators from the National Accounts by 64 branches of Eurostat.[16] Standard descriptive statistics are reported in Tables A18-A21 in Appendix A.

The distributions of labor shares and capital-output ratios, our key variables, remained relatively stable between 2011 and 2019, even though that of the capital-output ratio became less skewed (Fig. 4).

Notably, these distributions hide contrasting movements at the micro level between firms. Indeed, alongside the aggregate stability in the mean value of the labor share and its distribution - which means that the median firm did not experience any substantial changes in its labor share - there was a *redistribution between groups*. Considering firms in terms of their size, the moderate decline of the (weighted) aggregate labor share was driven by a reallocation of value added toward small and medium sized firms in the sample (SMEs), which nevertheless decreased both their average and median labor shares (*see* Fig. 5 - *panel A*). Among SMEs (defined as those with less than 250 employees), the labor shares in 2011 were 1.35% and 1.79% higher than the levels registered in 2019. On the other hand, firms with more than 250 employees performed better in terms of labor share growth, although they lost value-added shares. The average labor share of firms in different size classes is homogeneous (61%). This result is not surprising as our model states that the size of a firms is not a feature that influences its labor share. Instead, the firm's labor share is influenced by its underlying characteristics in terms of the variables identified as relevant in affecting its behavior.

Autor et al. (2020) reveal that if globalization or technological change led to a relocation of production towards the most productive firms within each industry of the economy, market concentration will rise as industries become dominated by the so-called "superstar firms". Since these firms are characterized by higher markups and a lower labor share of value added, the reallocation of output may be crucial to understand movements in the aggregate labor share.

The labor share of the most productive firms (the top 10% of the distribution labor productivity) is 35% lower than that of firms with medium levels of productivity and up to 48% lower than that of firms

[15] In the subset of countries analyzed, BvD reports Amadeus as having at least 75 percent coverage of all firms in each country, except for Iceland, Poland, and Luxembourg, where the database only captures 50–75 percent of firms, and Greece, where less than 25 percent of all firms are captured. Coverage of the small and medium enterprise (SMEs) is particularly good in Italy, Portugal, and Spain.

[16] Following the literature, a preliminary cleaning operation was performed. This is necessary to deal with negative returns on capital and firms with extremely low labour shares, which may be holding firms with little productive activity (established for tax purposes), or financial firms where value added does not reflect production.

Table 1
GMM estimates of the labor share equation. Dependent variable: $ln\ LS_{it}$ (*short-run*).

Code	Sector name	log(k)	σKL η=(-0.39)	σKL η=(-0.51)	log (TFP)	log (μ)	N obs	N. unique firms	Hansen's Chi sq	AR (1) z Stat.	AR (2) z Stat.
A	Agriculture	0.487* (0.262)	0.888	0.854	−1.149 (0.712)	−0.227 (0.188)	28,928	9514	31.14 p = 0.039	−6.969 p < 0.01	−1.049 p = 0.294
B	Mining and quarrying	0.567** (0.255)	0.860	0.817	4.757** (1.866)	−1.243*** (0.466)	3904	1275	19.06 p = 0.518	−3.91 p < 0.01	0.25 p = 0.802
C	Manufacturing	0.165 (0.136)	0.955	0.941	1.264*** (0.257)	−0.134 (0.340)	280,075	90,062	13.61 p = 0.192	−5.69 p < 0.01	−1.745 p = 0.0811
D	Electricity, gas and steam	−0.169 (0.316)	1.027	1.036	−0.647 (1.614)	0.0967 (0.454)	6537	2244	10.08 p = 0.967	−5.448 p < 0.01	−0.41 p = 0.682
E	Water supply and waste	−0.166 (0.258)	1.041	1.054	−0.0979 (2.051)	−0.198 (0.324)	11,979	3920	15.29 p = 0.759	−7.304 p < 0.01	0.841 p = 0.400
F	Construction	0.848*** (0.221)	0.752	0.676	9.831*** (2.753)	−4.655** (1.834)	88,233	30,581	8.626 p = 0.375	−2.945 p < 0.01	0.868 p = 0.385
G	Trade	0.723*** (0.103)	0.810	0.752	2.663** (1.077)	−1.507*** (0.187)	280,939	94,308	18.9 p = 0.0416	−13.78 p < 0.01	−0.325 p = 0.745
H	Transportation	−0.751 (0.666)	1.203	1.265	−1.343 (1.947)	0.304 (1.216)	56,395	19,300	2.477 p = 0.963	−3.644 p < 0.01	0.451 p = 0.652
I	Accomodation and food	0.296* (0.165)	0.916	0.891	2.765* (1.629)	−1.129 (0.831)	37,375	13,350	14.29 p = 0.112	−3.214 p < 0.01	−1.459 p = 0.145
J	Information and communication	0.308 (0.289)	0.909	0.882	0.0291 (0.828)	0.423 (0.342)	27,799	9643	17.39 p = 0.627	−10.15 p < 0.01	−0.669 p = 0.503
K	Financial and insurance	0.205 (0.334)	0.956	0.943	0.320 (1.438)	0.274 (0.377)	32,115	11,877	21.24 p = 0.383	−7.684 p < 0.01	−1.611 p = 0.107
L	Real estate	0.281 (0.539)	0.920	0.895	2.077 (2.868)	−3.752** (1.728)	20,055	7086	4.142 p = 0.844	−2.672 p < 0.01	0.111 p = 0.912
M	Professional activities	1.134*** (0.272)	0.684	0.587	3.882*** (1.151)	−1.053*** (0.386)	30,185	10,590	25.49 p = 0.183	−4.187 p < 0.01	0.0724 p = 0.942
N	Administrative activities	0.644** (0.335)	0.796	0.733	2.511* (1.412)	−1.549* (0.942)	28,621	10,191	21.27 p = 0.382	−6.813 p < 0.01	−0.455 p = 0.649
O	Public administration	−0.729 (0.695)	1.235	1.308	5.316** (2.161)	−1.608 (1.844)	5013	1797	5.46 p = 0.707	−1.615 p = 0.106	−0.0855 p = 0.932
P	Education	−0.136 (0.319)	1.040	1.052	0.962 (0.963)	0.194 (0.945)	14,384	4940	13.24 p = 0.867	−5.31 p < 0.01	1.185 p = 0.236
Q	Human health and social work activities	0.812* (0.459)	0.722	0.637	6.557** (2.867)	−4.670*** (1.298)	10,673	3672	3.796 p = 0.976	−5.31 p < 0.01	−0.266 p = 0.790
R	Arts and entertainment	0.641 (0.463)	0.827	0.774	0.700 (1.258)	0.629 (1.027)	8368	2984	23.69 p = 0.256	−7.968 p < 0.01	1.707 p = 0.0878
S	Other service activities	0.468** (0.191)	0.864	0.823	2.839*** (1.017)	−1.621* (0.849)	5686	1987	14.39 p = 0.810	−4.723 p < 0.01	−1.422 p = 0.155
ALL	Whole economy	0.848*** (0.221)	0.769	0.698	2.358*** (0.506)	−1.067*** (0.0888)	977,726	329,526	15.82 p = 0.148	−7.61 p < 0.01	1.045 p = 0.296

Note. Difference GMM estimation (short run coefficients). The values in parentheses are standard errors clustered at the firm level. The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively. Additional controls: sector-country specific year dummies.

Table 2
GMM estimates of the labor share equation. Dependent variable: *ln* LS_{it} (*long-run*).

Code	Sector name	log(k)	σKL η=(-0.39)	σKL η=(-0.51)	log (TFP)	log (μ)
A	Agriculture	0.563**	0.871	0.831	−1.329	−0.263
		(0.230)			(0.854)	(0.200)
B	Mining and quarrying	1.020**	0.749	0.671	8.554***	−2.236***
		(0.466)			(2.817)	(0.692)
C	Manufacturing	0.401	0.890	0.857	3.070***	−0.326
		(0.270)			(0.735)	(0.822)
D	Electricity, gas and steam	−0.333	1.054	1.070	−1.274	0.190
		(0.637)			(3.223)	(0.913)
E	Water supply and waste	−0.462	1.115	1.151	−0.272	−0.549
		(0.754)			(5.723)	(0.821)
F	Construction	0.0701	0.980	0.973	8.273***	−3.917***
		(0.293)			(2.206)	(1.073)
G	Wholesale and retail trade	0.962***	0.747	0.670	3.546**	−2.007***
		(0.0494)			(1.404)	(0.154)
H	Transportation and storage	−1.130	1.305	1.399	−2.022	0.457
		(0.937)			(3.210)	(1.895)
I	Accommodation and food	0.443**	0.875	0.837	4.149	−1.693
		(0.225)			(3.174)	(1.494)
J	Information and communication	0.675	0.801	0.740	0.0638	0.929
		(0.735)			(1.811)	(0.746)
K	Financial and insurance	0.551	0.882	0.846	0.861	0.739
		0.845			(3.841)	(0.940)
L	Real estate	1.237	0.647	0.538	9.144	−16.52
		(3.036)			(11.22)	(27.70)
M	Professional activities	1.997***	0.444	0.273	6.837***	−1.860***
		(0.476)			(1.557)	(0.673)
N	Administrative activities	1.354*	0.570	0.438	5.124	−3.161
		(0.789)			(3.134)	(2.108)
O	Public administration	−0.736	1.238	1.311	5.368***	−1.624
		(0.271)			(1.584)	(1.630)
P	Education	−0.537	1.156	1.204	3.807	0.767
		(1.445)			(2.975)	(3.962)
Q	Human health and social	1.215*	0.585	0.457	9.817**	−6.992***
		(0.724)			(4.378)	(2.088)
R	Arts and entertainment	2.181	0.411	0.230	2.382	2.139
		(1.940)			(4.155)	(3.774)
S	Other service activities	0.959	0.722	0.637	5.822***	−3.325*
		(0.430)			(2.172)	(0.1.984)
ALL	Whole economy	1.132***	0.691	0.597	3.147***	−1.424***
		(0.376)			(0.556)	(0.283)

Note. Difference GMM estimation (long run coefficients). The values in parentheses are standard errors clustered at the firm level. The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively. Additional controls: sector-country specific year dummies.

with low productivity levels (*see* Fig. 5 - *panel B*). In addition, more productive firms gained value-added shares compared to those with medium-low productivity over the period analyzed (+2.65%) (Table A5). This means that the observed fall in the labor share is partially ascribable to the reallocation of value added between heterogeneous firms rather than a general fall within incumbent firms. However, as shown with the shift-share analysis in Section 3, this fact alone *cannot explain* the observed changes in labor share in the EU. To shed light on this issue, *changes in intra-firm labor share* must be analyzed, which is what we do in the next subsection.

4.3. Results

When we estimate equation (5) for the whole economy, we obtain the following short (SR) and long run (LR) elasticities (standard errors in parenthesis)[17]

$$\begin{aligned} \text{SR}: log\left(LS_{i,t}\right) = & \underbrace{0.335}_{(0.139)}\log\left(LS_{i,t-1}\right) - \underbrace{0.0841}_{(0.120)}\log\left(LS_{i,t-2}\right) \\ & + \underbrace{0.848}_{(0.220)}\log\left(k_{i,t}\right) + \underbrace{2.358}_{(0.506)}\log\left(TFP_{i,t}\right) - \underbrace{1.067}_{(0.0888)}\log\left(\mu_{it}\right) \end{aligned} \tag{7}$$

$$\text{LR}: log\left(LS_{i,t}\right) = \underbrace{1.132}_{(0.375)}\log\left(k_{i,t}\right) + \underbrace{3.147}_{(0.556)}\log\left(TFP_{i,t}\right) - \underbrace{1.424}_{(0.283)}\log\left(\mu_{it}\right)$$

$$Hansen's\ Chi\ sq = 15.82\ (p = 0.148);\ AR(1)\ Z = -7.61\ (p < 0.01);\ AR(2)\ Z = 1.04\ (p = 0.296)$$

Testing the validity of the dynamic model and instruments used, we find that the Hansen's overidentification test based on one-stage estimates does not provide evidence of misspecification. We cannot reject the null hypothesis of joint validity of all instruments. Arellano and Bond's (1991) specification test for the absence of second-order serial correlation in first-differenced residuals is also passed. The estimation results hint at the appropriateness of a dynamic instead of a static model. From equation (7) emerges that the capital-output ratio is positively and significantly related to the labor share, which indicates departure from the Cobb-Douglas production function. The positive coefficient further suggests that labor and capital are gross complements, a finding which we share with part of the previous literature and is likely to be related to the (unobserved) shares of skilled labor and the composition of capital assets in the economy (Mallick and Sousa, 2017; Berlingieri et al., 2022).

[17] Results for short run elasticities refer to the cumulated sum of the coefficients for all lags for each independent variable (i.e., $\sum_l \beta_l$, $\sum_l \gamma_l$ and $\sum_l \delta_l$). Long run elasticities, instead, are estimated as the ratio between short-run coefficients and $\left(1 - \sum_l \lambda_l\right)$, which corresponds to the case where the dependent variable is at its steady state. In the Online Appendix we show that the results are robust to the exclusion of either a country or a sector at a time (Tables A11 and A12).

As a check of the results, we use the estimated coefficients to compute industry-specific measures of the elasticity of substitution between K and L, σ_{KL}. From equation (5), we compute it as: $\sigma_{KL} = -\left(1 + \frac{\partial \log LS}{\partial \log k} \overline{LS} \bullet \eta\right)$, where η is the elasticity of the labor demand with respect to the wage and $\overline{LS}$ is the average labor share. Several estimates of wage elasticity are available in the literature. We draw on Lichter et al. (2015), which build on 942 elasticity estimates from 105 different studies to find an overall mean (median) own-wage elasticity of labor demand of −0.508 (−0.386). For a value of $\eta = -0.51$, the coefficient for the capital-output ratio (0.85) implies an average capital-labor elasticity of 0.7, which is statistically different from the Cobb-Douglas value of 1. Table 1 reports the estimates of our basic specification, equation (5), broken down by sector. The results of the same equation estimated for the manufacturing sub-sectors (at the two-digit NACE level) are shown in Table A6. The relationships between a firm's capital-output ratio and its labor share turns out to be positive in 14 out of 19 industries considered (but not statistically different for zero for p-value<0.1 in five cases), while it is estimated to be negative in the remaining 5 industries (but not distinguishable from zero with p-value<0.1 in all cases). Among industries where the relationship is positive and statistically significant, this latter is larger in magnitude (above 0.5) in professional activities (1.13), construction (0.85), human health and social works (0.81), wholesale and retail trade (0.72), administrative activities (0.64), arts and entertainment (0.64) and mining (0.57). In contrast, if we look at sectors where the relationship between the capital output ratio and the labor share is negative (though not statistically significant), this latter is particularly marked in transports (−0.75) and the public administration (−0.73). As far as manufacturing is concerned, the same relationship goes from (0.72) in the production of basic metal products to (−0.27) in computer, electronic and optical products. An elasticity of substitution of less than one at the aggregate level is consistent with the results of Wemy (2021) and other studies, indicating that estimates based on long-run relationships with income shares may produce unreasonably large values. At the same time, as already stressed by the literature, the great heterogeneity in the magnitude of this effect at the industry-level is likely to be related to the shares of unskilled labor and the shares of tangibles, intangibles and robot assets in different firms (Havranek et al., 2020; O'Mahony et al., 2021; Acemoglu and Restrepo, 2020).

Table 1 (for the one-digit NACE industries) and A6 (for the two-digit manufacturing subsectors) show our estimates for σ_{KL} with η=(−0.51) (column 5). We obtain elasticities slightly above one in five industries, ranging from 1.04 to 1.31 and lower than one in the remaining fourteen industries, with values between 0.59 and 0.94. For comparison, in the column immediately to the left (column 4) we also report the same value obtained with an elasticity of labor demand of −0.39, as in the original article by Bentolila and Saint Paul. However, we do not observe any major changes in our results and the elasticity is significantly different from one also in this case. These values for the elasticity of substitution estimated with micro data lie in between those found by other researchers (Knoblach and Stöckl, 2020). Nevertheless, our computed elasticities depend on positing an external value for η, since we cannot provide direct estimates of σ.

The first shifter of the *LS*-*k* relationship, that is firm-level *TFP*, is meant to capture the effect of capital-augmenting - or, more generally, 'not labor-augmenting' - technological progress on the labor share. On average, an increase in the TFP of 1% leads to an increase of roughly 2.36% in the aggregate labor share. The same coefficients turn out to be positive and significant also in the public administration (5.32), mining (4.78), professional activities (3.88), other services (2.84), accommodation and food (2.77), wholesale and retail trade (2.66), administrative activities (2.51) and manufacturing (1.26). If TFP is strictly capital-augmenting, its impact on the labor share should have the same sign of the capital-output ratio (Bentotila and Saint-Paul 2003; Bassanini and Manfredi, 2014; O'Mahony et al., 2021).[18] This is the case in all sectors where we obtain significant coefficients. Similarly, the positive sign of *k* means that capital-labor substitution may only have been a significant factor in the decline of labor share if capital intensity decreased over the period of analysis (which is empirically observed in our data). Notably, this latter finding also confirms the results of other studies, including those at higher levels of aggregation (Hutchinson and Persyn, 2012).

Regarding markups, we find a negative and significant relationship with the labor share in the whole economy (−1.07). This reflects negative (and significant) coefficients in 8 of the 19 industries considered. Markups are particularly strongly negatively correlated with within-firms labor shares in human health and social work activities, construction, real estate, other services, administrative activities, trade and mining. These results are consistent with Barkai's (2020) model, which predicts a decrease in the within-firm's labor share because of declining competition. Therefore, an increase in markups may have the *dual role* of decreasing the labor share within and between firms (Baqaee and Farhi, 2019; De Loecker et al., 2020).

Table 3
GMM estimates of the labor share equation with nonlinear terms for *k*: elasticity of LS with respect to capital/output ratio at different quartiles of the capital/output ratio. Dependent variable: $ln\ LS_{it}$ (*short-run*).

Code	Sector name	Slope k Linear spec	Slope k Cubic. Specific.: Q1	Slope k Cubic. Specific.: Q2	Slope k Cubic. Specific.: Q3
A	Agriculture	0.487	0.404	0.413	0.424
B	Mining and quarrying	0.567	0.650	0.495	0.326
C	Manufacturing	0.165	0.422	0.582	0.752
D	Electricity, gas and steam	−0.169	−0.241	−0.461	−0.692
E	Water supply and waste	−0.166	−0.235	−0.322	−0.411
F	Construction	0.848	−0.044	0.012	0.073
G	Wholesale and retail trade	0.723	−0.010	−0.002	0.006
H	Transportation and storage	−0.751	−1.017	−0.933	−0.842
I	Accommodation and food services	0.296	0.470	0.275	0.048
J	Information and communication	0.308	0.177	0.405	0.654
K	Financial and insurance	0.205	0.955	1.030	1.103
L	Real estate	0.281	0.071	0.199	0.346
M	Professional activities	1.134	0.697	0.778	0.864
N	Administrative activities	0.644	0.498	0.387	0.268
O	Public administration and defense	−0.729	−0.577	−0.497	−0.415
P	Education	−0.136	0.017	−0.137	−0.298
Q	Human health and social services	0.812	0.060	0.075	0.092
R	Arts and entertainment	0.641	0.657	0.525	0.397
S	Other service activities	0.468	0.351	0.408	0.465
ALL	Whole economy	0.848	1.280	1.237	1.194

Note. The table with coefficient estimates can be found in the Online Appendix (Table A7).

[18] As shown by Bentotila and Saint-Paul (2003), under capital-augmenting technical progress productivity shifts do affect the *LS*-*k* curve in a way which implies a strong restriction. As a_i always multiplies k_i in (4), we must have: $k_i(\log LS_i / \partial \log k_i) = A_i(\log LS_i / \partial \log A_i)$. This is a restriction with respect to the regression coefficients of LS_i on k_i and a_i. We find Correspondence with this theoretical prediction in our estimates.

Table 4
GMM estimates of the labor share equation with nonlinear terms for *k*: elasticity of LS with respect to capital/output ratio at different quartiles of the capital/output ratio. Dependent variable: $ln\ LS_{it}$ (*long-run*).

Code	Sector name	Slope k Linear spec	Slope k Cubic. Specific.: Q1	Slope k Cubic. Specific.: Q2	Slope k Cubic. Specific.: Q3
A	Agriculture	0.563	0.809	0.828	0.850
B	Mining and quarrying	1.020	1.095	0.834	0.550
C	Manufacturing	0.401	0.438	0.605	0.782
D	Electricity, gas and steam	−0.333	−0.392	−0.757	−1.143
E	Water supply and waste	−0.462	−0.759	−1.038	−1.322
F	Construction	0.070	−0.038	0.010	0.063
G	Wholesale and retail trade	0.962	−0.026	−0.005	0.016
H	Transportation and storage	−1.130	−1.762	−1.616	−1.455
I	Accommodation and food services	0.433	1.817	1.068	0.195
J	Information and communication	0.675	0.412	0.953	1.543
K	Financial and insurance	0.551	0.812	0.876	0.938
L	Real estate	1.237	0.089	0.249	0.433
M	Professional activities	1.997	1.112	1.241	1.379
N	Administrative activities	1.354	0.874	0.680	0.472
O	Public administration and defense	−0.736	−0.981	−0.844	−0.704
P	Education	−0.537	0.074	−0.556	−1.219
Q	Human health and social services	1.215	0.101	0.125	0.154
R	Arts and entertainment	2.181	1.013	0.808	0.611
S	Other service activities	0.959	0.595	0.691	0.789
ALL	Whole economy	1.132	2.487	2.363	2.238

Note. The table with coefficient estimates can be found in the Online Appendix (Table A8).

Similar observations can be made for the long-run marginal effects (which are reported in Table 2 below). Specifically, while for the economy there is an increase in the impact of the explanatory variables on the labor share of about 1.33, the multiplicative effect given by $(1-\sum\lambda)^{-1}$ is particularly relevant in real estate, education, and arts and entertainment.

At this point, we would like to draw attention to the most important result of our paper. Given that the theoretical model suggests potential nonlinearities in the elasticity of the labor share with respect to the capital-output ratio, we try to capture this effect by means of a more flexible relationship between *k* and the *LS*. This is done by employing a *third-degree polynomial* and by adding the squared (k^2) and cubic (k^3) log capital-output ratio.

The cubic functions used to capture the relationship allows the impact of the capital-output ratio on the labor share to change with the value of *k*. As the value of *k* increases (or decreases), the impact of the dependent variable may also increase or decrease along a concave or convex function. Table 3 presents our empirical estimations for the nonlinear model in the short run.

The third column reports the linear specification as a benchmark.[19] The other columns report the elasticity of *LS* with respect to *k* in the first, second and third quartiles of the sample distribution of *k*. In Tables A9-10 we show the corresponding elasticity of substitutions between capital and labor in both the short and the long-run.

Looking at the elasticity of the labor share with respect to the capital-output ratio in the linear model and comparing it with the median quartile of the cubic model (Q2), we observe that the elasticity of substitution is overestimated (on average) when the *LS-k* curve is forced to be fitted with a linear relationship and thus a constant elasticity (Figure A10). On the one hand this confirms the concerns of Kazi (1980) who shows how assuming a CES production function may bias the estimation of the elasticity of substitution. On the other it provides evidence in favor of the more general argument of Growiec and Mućk (2020), which question the belief that the elasticity of substitution is a technological constant, unchanged by factor accumulation. Finally, depending on the sector, the bias introduced may be upwards or downwards. This latter is particularly large (above 0.2 absolute points) in Human health and social services, Construction, Trade and Finance. As with the linear model, in Table 4 we report the estimated values of elasticities at the various quartiles of *k* in the long run.

Notably, the cubic relationship between LS and *k* should be preferred for the whole economy and for all the industries considered.[20] Further, the capital-output ratio enters the equation with a positive sign but with varying magnitude. This result reflects the degree of sustainability of capital and labor in different sectors. The curves for the whole economy as outlined by the linear and cubic models are shown in Fig. 6.

As it stands out from Fig. 6 (*panel B*), the relationship between *k* and *LS* is not constant along the capital-output range, nor it is the elasticity of substitution (Tables A7 and A8). While the elasticity of *LS* with respect to *k* is estimated to be 1.28 at the first quartile (Q1), it decreases to 1.19 in Q3, thus implying an increase in the elasticity of substitution as we move to the right in the *LS-k* curve (from 0.54 to 0.58). This means that a CES-type production function with a constant elasticity of substitution would overestimate the elasticity of substitution for the whole economy and hence the relationship between *k* and the labor share. Moreover, this overestimation would be stronger in the lowest percentiles of *k* (i.e., moving to the right in the *LS-k* curve) and in the long run.

Remarkably, this result becomes relevant when put in relation to sectoral heterogeneity (Figs. 7 and 8). In this perspective, an interesting point concerns the fact that, as expected, there are many sectors (agriculture, mining, manufacturing, ICT, finance, real estate, professional and administrative activities, arts and entertainment and services) where both linear and nonlinear specification (at all quartiles) estimate a positively sloping curve and thus an elasticity of substitution between capital and labor lower than one. Then there are several industries where the two estimates (linear and cubic) have an equal but negative sign (i.e., elasticity of substitution greater than one). This is the case with utilities, transports and the public administration. Finally, there are some sectors where nonlinearities are so pronounced that the elasticity of substitution changes sign along the relevant range, i.e., construction, wholesale and retail trade and education. Notably, in some sectors the relationship between *k* and *LS* takes the form of an inverted U with a unique turning point within the relevant range of *k*.

[19] It should be noticed that the best GMM specification for the linear case in terms of lags and instruments for a sector could be different from the best GMM specification for the cubic case. These differences could also result in different sub-samples for the two estimations, which could make the comparison not ideal in some cases.

[20] Indeed, the cubic term turns out to be statistically significant in all specifications.

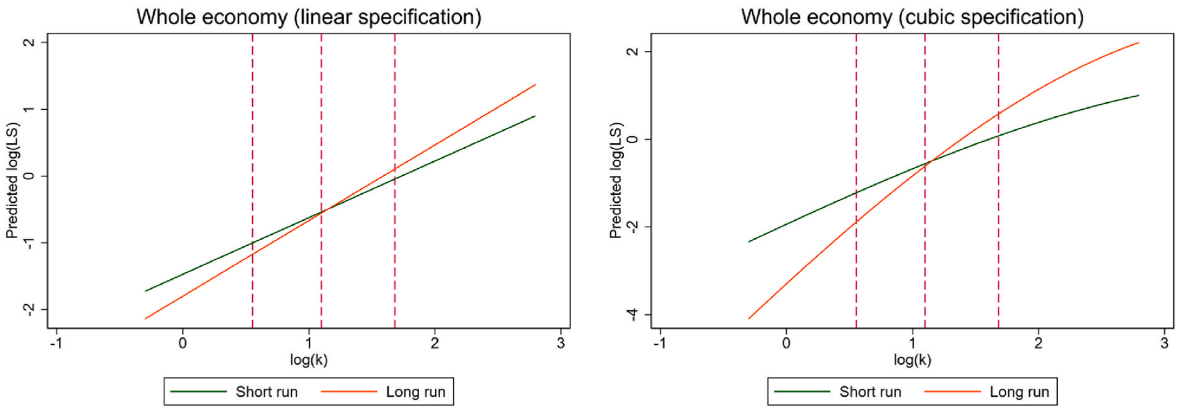

Fig. 6. The labor share/capital-output (LS-k) curve for the aggregate economy, linear and cubic specifications. Note. Panel (a): linear model, whole economy; Panel (b): cubic model, whole economy. log(k) in the x-axis, predicted log (LS) in the y-axis. Linear vs cubic specification. Dashed vertical lines, from left to right, refer, respectively, to the i. First quartile; ii median; iii. Third quartile. The top and bottom percentiles of log(k) are trimmed from the figure.

4.4. Discussion

As pointed out by the literature, the heterogeneity in the relationship between capital-output ratio and the labor share cannot be captured by the rigid division of the economy into production and service sectors, as may reflect the specific mix of capital and the different qualifications of workers in each industry and firm considered (O'Mahony et al., 2021). Due to the lack of more granular data on capital assets and skills of workers at the firm level, we cannot provide more precise considerations in this regard. However, a nonlinear relationship between the capital-output ratio and the labor share has some interesting implications for both macroeconomic theory and policy directions. We discuss the former point below and leave the latter to the concluding section.

Even if we do not assume that capital per unit of output and the elasticity of substitution are linked by any specific functional form (the empirical specification is valid for any CRS production function), the results are consistent with the literature on endogenous (and variable) elasticity of factor substitution. Recently, Growiec and Mućk (2020), generalized the normalized CES production function by allowing the elasticity of substitution to vary isoelastically with the capital-output ratio (IEES). As opposed to the cases of the Cobb–Douglas and CES, in IEES functions the relative factor shares no longer depend monotonically on k. Instead, there exists a unique point of reversal on the *LS-k* curve, coinciding with the point where the elasticity of substitution crosses unity, $\sigma(k) = 1$. They show that the aggregate production function in the post-war US economy implies that the elasticity of substitution σ between capital and labor has been systematically positively related to the capital-output ratio and that σ has been consistently below unity, obtaining clear evidence of a downward trend in this parameter across the following periods. Our results, although over a shorter time and using European firm-level data, are certainly consistent with this view.

A positive *LS-k* relationship at the firm level and an elasticity of substitution less than one has interesting implications to understand aggregate trends. Indeed, it is compatible with a fall in the labor share only in the presence of a reduction in the effective growth of the capital-output ratio. Since the latter fact is observed in our data, in the last paragraph we try to verify if the observed movement in k, together with the estimated conditional elasticity, are consistent with the greater importance of the decline in the within-firm labor share in explaining the changes in labor share observed in EU industries.

As we have made clear throughout the paper, our contribution to the literature is mainly empirical as we look at the *conditional correlation* between labor share and the capital-output ratio, using different types of functional relationships. Therefore, although we were guided by a theoretical model, we did not make *causal references* in the identified relationships. In this final section we take our analysis one step further and try to assess the proportion of aggregate changes of the labor shares explained by movements of k, making use of the results from Tables 1 and 4 These results are useful to compare the linear (Table 5) with the nonlinear model (Table 6) and provide an initial evaluation of the direction of the estimates to be left for further investigation in subsequent studies.

As can be seen from the tables, the contribution of k to explaining average changes in the labor share are either negligible or extremely relevant, depending on the sector considered. In fact, when it comes to explaining the variance of the labor share at the firm level, k is only one of our explanatory variables. We can observe firms and sectors in which k explains more than 100% of the labor share, in which case it is likely that markup played a (greater than average) role in explaining variations in the labor share within firms. Conversely where k just explains a small proportion of the change in the labor share, the remaining proportion could be explained by capital augmenting technological change as proxied by TFP. However, we do not make further considerations in this regard as this would go beyond our main research question. Finally, note how the predictions of the linear and cubic models (the latter evaluated at the median value of k) are aligned with each other, despite slightly different estimation samples due to the model construction procedures. This is undoubtedly a sign of the good capability of the models and the correctness of the specifications employed.

5. Conclusions

A vast literature has studied changes in the labor share, either at the country, sectoral and firm-levels. In this paper, we use longitudinal data on a sample of firms from 20 EU countries over the period 2011–2019 to shed light on the firm level determinants of labor share. We first document a startling fact: changes in the industry labor share in Europe cannot be totally explained by intra-industry restructuring (i.e., the "superstar firms" theory). This leads us to focus on the *within-firm processes of income distribution*.

We employ the Bentolila and Saint-Paul (2003) model as benchmark focusing on the relationship between the labor share and the capital-output ratio. With respect to this paper, we take a step forward using firm level data to identify the shifting factors in the *LS-k* curve. From a *theoretical perspective*, the firm-level focus is relevant to single out compositional effects from actual firms' decisions: labor share is the result of production decisions and wage-setting processes that take place inside heterogenous firms. From an *empirical one*, the panel dimension of our data ensures that our results are not driven by unobserved attributes of firms that may be correlated with organizational decisions.

We estimate a positive relationship between the labor share and the

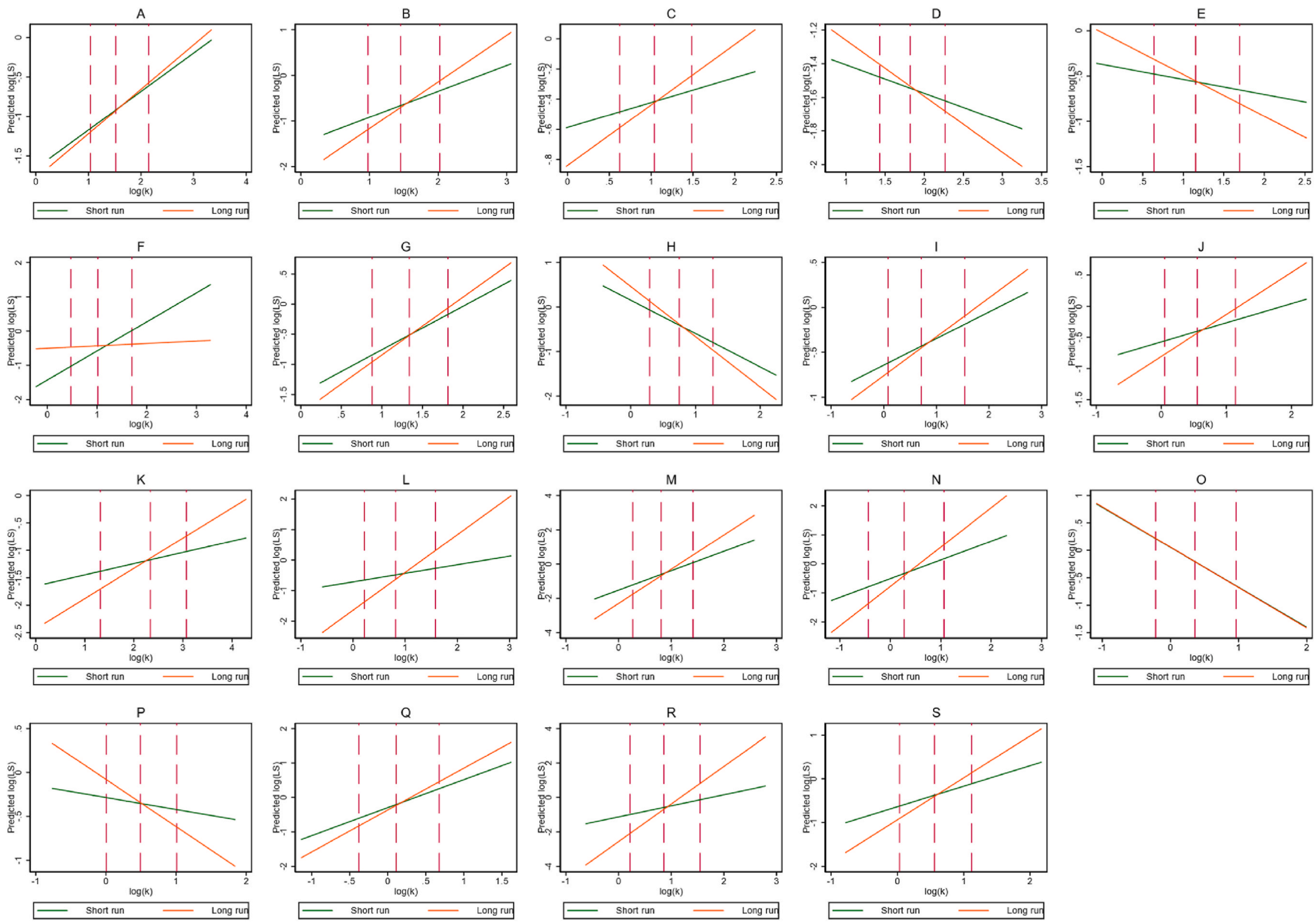

Fig. 7. The labor share/capital-output curve by industry, *short-run* vs *long-run* (linear specification). Note. The estimates shown are those in Table 2 for all the 19 1-digit NACE rev. 2. Industries considered. Industries are: A. Agriculture; B. Mining; C. Manufacturing; D. Electricity and gas; E. Water supply and waste; F. Construction; G. Wholesale and retail trade; H. Transportation and storage; I. Accomodation and food; J. Information and communication; K. Financial and insurance; L. Real estate; M. Professional activities; N. Administrative activities; O. Public administration; P. Education; Q. Human health and social; R. Arts and entertainment; S. Other services. Log(k) in the x-axis, predicted log (LS) in the y-axis. Linear vs cubic specification. Dashed vertical lines, from left to right, refer, respectively, to the i. First quartile; ii median; iii. Third quartile. The top and bottom percentiles of log(k) are trimmed from the figure.

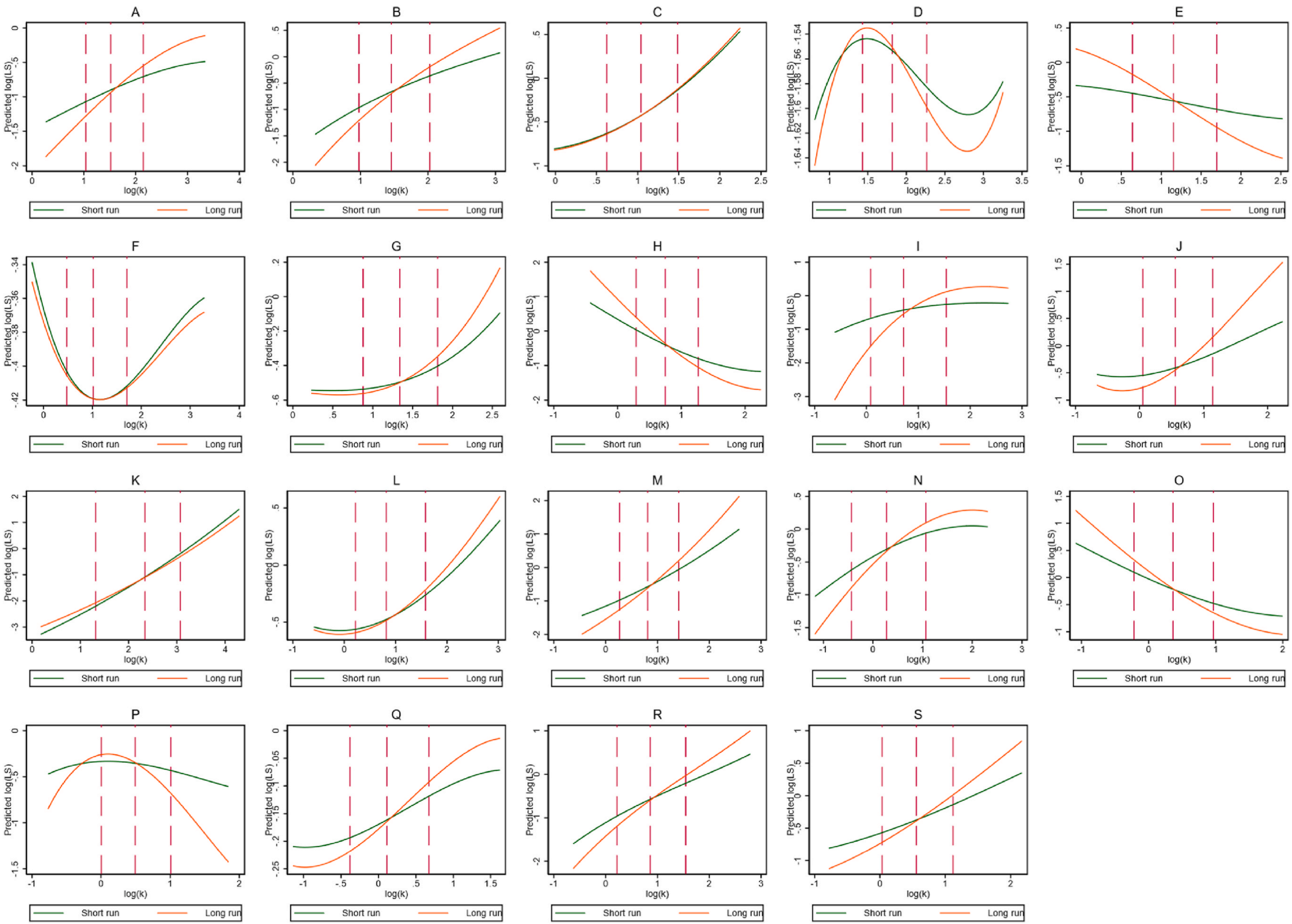

Fig. 8. The labor share/capital-output curve by industry, *short-run* vs *long-run* (cubic specification). Note. The estimates shown are those in Table 2 for all the 19 1-digit NACE rev. 2. Industries considered. Industries are: A. Agriculture; B. Mining; C. Manufacturing; D. Electricity and gas; E. Water supply and waste; F. Construction; G. Wholesale and retail trade; H. Transportation and storage; I. Accomodation and food; J. Information and communication; K. Financial and insurance; L. Real estate; M. Professional activities; N. Administrative activities; O. Public administration; P. Education; Q. Human health and social; R. Arts and entertainment; S. Other services. Log(k) in the x-axis, predicted log (LS) in the y-axis. Linear vs cubic specification. Dashed vertical lines, from left to right, refer, respectively, to the i. First quartile; ii median; iii. Third quartile. The top and bottom percentiles of log(k) are trimmed from the figure.

Table 5
The impact of the capital-output ratio on labor share, 2011–2019 (linear specification).

Code	Sector name	Average log (k)	Actual cumulative growth rate of k	Actual cumulative growth rate of LS	Growth of LS predicted by k (short run)	Growth of LS predicted by k (long run)
A	Agriculture	1.590	0.040	0.087	0.020	0.023
B	Mining and quarrying	1.540	0.003	0.019	0.002	0.004
C	Manufacturing	1.084	−0.009	0.012	−0.001	−0.004
D	Electricity, gas and steam	1.771	−0.041	0.018	0.007	0.014
E	Water supply and waste	1.166	−0.051	0.009	0.008	0.024
F	Construction	1.168	−0.044	−0.005	−0.037	−0.003
G	Wholesale and retail trade	1.388	−0.019	0.015	−0.013	−0.018
H	Transportation and storage	0.838	0.006	0.065	−0.005	−0.007
I	Accommodation and food	0.895	−0.091	−0.016	−0.027	−0.039
J	Information and communication	0.638	−0.017	−0.006	−0.005	−0.012
K	Financial and insurance	2.018	0.000	−0.027	0.000	0.000
L	Real estate	0.886	0.006	0.007	0.002	0.008
M	Professional activities	0.889	−0.019	0.011	−0.021	−0.037
N	Administrative activities	0.398	−0.015	0.014	−0.010	−0.021
O	Public administration	0.440	−0.005	0.002	0.003	0.004
P	Education	0.541	−0.028	0.026	0.004	0.015
Q	Human health and social	0.217	−0.001	0.026	−0.001	−0.001
R	Arts and entertainment	0.892	−0.079	−0.011	−0.051	−0.173
S	Other service activities	0.639	−0.019	0.000	−0.009	−0.018
ALL	Whole economy	1.144	−0.017	0.014	−0.014	−0.019

Table 6
The impact of the capital-output ratio on labor share, 2011–2019 (cubic specification).

Code	Sector name	Average log (k)	Actual cumulative growth rate of k	Actual cumulative growth rate of LS	Growth of LS predicted by k (short run)	Growth of LS predicted by k (short run)
A	Agriculture	1.590	0.040	0.087	0.072	0.128
B	Mining and quarrying	1.540	0.003	0.019	0.008	0.014
C	Manufacturing	1.084	−0.009	0.012	−0.011	−0.013
D	Electricity, gas and steam	1.771	−0.041	0.018	0.043	0.075
E	Water supply and waste	1.166	−0.051	0.009	0.042	0.132
F	Construction	1.168	−0.044	−0.005	−0.037	−0.003
G	Wholesale and retail trade	1.388	−0.019	0.015	−0.013	−0.017
H	Transportation and storage	0.838	0.006	0.065	−0.015	−0.024
I	Accommodation and food	0.895	−0.091	−0.016	−0.075	−0.225
J	Information and communication	0.638	−0.017	−0.006	−0.014	−0.031
K	Financial and insurance	2.018	0.000	−0.027	0.002	0.002
L	Real estate	0.886	0.006	0.007	0.004	0.011
M	Professional activities	0.889	−0.019	0.011	−0.046	−0.077
N	Administrative activities	0.398	−0.015	0.014	−0.015	−0.029
O	Public administration	0.440	−0.005	0.002	0.006	0.007
P	Education	0.541	−0.028	0.026	0.007	0.029
Q	Human health and social	0.217	−0.001	0.026	−0.001	−0.001
R	Arts and entertainment	0.892	−0.079	−0.011	−0.129	−0.293
S	Other service activities	0.639	−0.019	0.000	−0.018	−0.034
ALL	Whole economy	1.143	−0.017	0.014	−0.063	−0.113

capital-output ratio and thus an elasticity of substitution between capital and labor less than one, on average. Further, we document a decrease in the capital-labor ratio over the period considered, which is compatible with the observed decrease in the *within-firms* labor share. In addition, we also show that markups are important sources to explain the evolution of the labor share at the firm level and within sectors. Hence their *dual role*. On the one hand, product market concentration rises because industries are dominated by superstar firms, which have high markups and a low labor share of value-added, on the other a growth in markups may lead to a further decline in labor share within firms.

Then, we extend our baseline empirical specification to investigate the properties of the relationship between the labor share and capital accumulation. Specifically, we estimate the model with nonlinear terms for capital in a cubic fashion, also accounting for dynamic adjustments. Our analysis points to *significant nonlinearities* at the aggregate and, notably, sectoral level. This evidence states that the relationship between the labor share and the capital-output ratio could even be non-monotonic along the relevant capital domain of *k*. Although our data do not allow for further investigation in this regard, the different forms of the relationship with capital in different sectors of the economy may be related to the presence of skilled workers and specific types of capital assets. Even in the case where the relationship is convex but monotonic, as it is for the aggregate economy and most sectors, the elasticity of substitution tends to increase or decrease significantly as capital gets accumulated. This result is consistent with the recent study of Growiec and Mućk (2020) which employ variable (isoelastic) elasticity of substitution production function instead of the traditional CES. This also confirms the concerns of Kazi (1980) that a CES production function may introduce a bias in the estimate of the elasticity of substitution.

All in all, our results highlight a key role in product market regulatory policies in sustaining labor share and suggest that policies aimed at fostering capital deepening to improve labor productivity and technology advancements might have unexpected distributional effects, respect to the goals set by the policy maker.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2023.106327.

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