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Capital-Labor Substitution and the Decline in Labor’s Share

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Abstract

The studies of Piketty (2014) and Karabarbounis and Neiman (2014) show that labor shares around the world decline because capital robustly substitutes for labor as its relative cost declines. Because these studies use aggregate data, they cannot show how heterogeneous firms’ decisions shape aggregate labor shares. Using Chinese manufacturing data, we show firms’ labor shares differ substantially because of the massive heterogeneity of their capital intensities, product markups, and ownerships. Although capital and labor are substitutes and the cost of capital declines, our counter-factual analysis indicates the quantitative impact of capital-labor substitution on declining labor shares is small.

Keywords: Labor’s share, Capital-labor substitution, China
JEL Classification: E25, O19, O52.
1 Introduction

In a celebrated study, Piketty (2014) explains declining labor shares in many countries since the 1980s using an aggregate growth model where capital and labor are substitutes, and the costs of capital relative to labor decline. Karabarbounis and Neiman (2014) estimate aggregate production functions and show that Piketty’s capital-labor substitution mechanism accounts for a substantial share of the decline in labor’s share. However, firms within the countries face different costs of capital relative to labor (e.g., Hsieh and Klenow, 2009; Brandt, Tombe, and Zhu, 2013), and exhibit variations in their labor shares (e.g., Leonardi, 2007; Bockerman and Maliranta, 2012; Autor et al., 2017). As such, using aggregate data, it is not possible to study how heterogeneous firms’ decisions shape aggregate labor shares.

In this paper, we study the capital-labor substitution mechanism at the firm level in China’s manufacturing sector. This is an ideal environment for several reasons. First, capital and labor are substitutes in production processes: the elasticity of substitution between capital and labor substantially exceeds unity in the overwhelming share of 3-digit Chinese manufacturing sectors (Berkowitz, Ma, and Nishioka, 2017). Second, during the 1999-2006 period, capital intensities—capital labor ratios—in the manufacturing sector increased by roughly 30 percent, indicating the costs of capital relative to labor fell. Finally, labor shares in the manufacturing sector declined by 7.1-percentage points from 1999 to 2006, which is an exceptionally rapid per-decade decline for most countries since 1975 (see Karabarbounis and Neiman, 2014, Figure 3).

Figure 1 illustrates the heterogeneity in labor shares across firms in Chinese manufacturing sector from the balanced sample of 28,220 firms in 1999 and 2006. The range of labor shares is widely distributed, and the probability density function shifted to the left from 1999 to 2006, indicating the mass of the firms with lower values of labor shares increased. To estimate the impact of the capital-labor substitution mechanism on this shift, we extend a firm-level model of labor shares from Azmat, Manning, and Van Reenen (2012) and Autor, Dorn, Katz, Patterson, and Van Reenan (2017) that links a firm’s labor share to its relative capital-labor cost. This model

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Piketty’s (2014) and Karabarbounis and Neiman’s (2014) results are controversial because most of the national-, industry- and firm-level estimates from advanced countries show that capital and labor are complements in production processes (see León-Ledesma, McAdam, and Willman, 2010; Chirinko, Fazzari, and Meyer, 2011; Oberfield and Raval, 2014; Acemoglu, 2003, p.3 and Footnote 3; Antrás, 2004, section I). Oberfield and Raval (2014), however, do find that the capital-labor substitution elasticity is about 1.1 in India. They also find that even when firm- and industry-level elasticity of substitutions exceed unity, the substitution elasticity of the aggregate production function can be less than unity.
also highlights the impact of a firm’s product markup on its labor share. In order to conduct a counter-factual analysis, we use sector-level estimates of the structural parameters of the model and predict the firm-level distribution of labor shares in 1999. We decompose the shift in the distribution of labor shares by increases in capital intensities over time (reflecting the declining costs of capital relative to labor) and, additional factors including the changes in product markups and the ownership-specific changes in compensation schemes. Finally, quantile regression methods in Koenker and Bassett (1978) and Firpo, Fortin, and Lemieux (2009) are used to test for the statistical significance of the shifts in the distributions.

Surprisingly, the capital-labor substitution mechanism accounts for only 1-percentage point of the overall 7.1-percentage point decline in labor shares. And, other factors that cannot be incorporated in aggregate data including changes in firm-level distribution of product markups, the composition of firms, and changes in firm ownership, have much stronger quantitative effects.

The next two sections describe the data and the model. Section 4 contains a brief overview of the paper’s estimation strategy; section 5 presents the counter-factual analysis; and section 6 concludes.

2 Labor Shares at the Firm Level

The data is taken from the Chinese Annual Surveys of Industrial Production (ASIP), which covers all state owned enterprises (SOEs) and private firms with total annual sales exceeding 5 million RMB per year or roughly 612,000 US dollars. Our major firm-level outcome variable is payments to labor as a share of value added or labor’s share:

\[ s_{it} = \frac{w_{it}L_{it}}{VA_{it}} \] (1)

where \( w_{it}L_{it} \) is labor compensation of firm \( i \) in year \( t \), and \( VA_{it} \) is a measure of value added using the production approach.\(^3\)

\(^2\)Our labor shares measure excludes private manufacturing firms with sales less than 5 million RMB per year. Gollin (2002) notes that in the system of national accounts the income of small firms in which the proprietors are self-employed is generally treated as capital income. Gollin (2002) then finds that labor shares become more stable once the income of self-employed proprietors is treated as wage income. In China the income of self-employed proprietors is classified as labor income during 1997-2003 and then as capital income since 2004. However, this is not a problem for our analysis because there are no self-employed proprietors in our sample.

\(^3\)This approach computes value added from gross output \( (p_{it}Q_{it}) \) minus spending on intermediate inputs \( (\hat{p}_{it}M_{it}) \).
Our baseline measure of aggregate labor shares is lower than the comparable figures from the national accounts. This is because our labor compensation measure includes wage and unemployment insurance while labor compensation in the national accounts include wages and a broader set of benefits paid to labor. Because we focus on the distribution of firm-level labor shares and compensation schemes differ by ownership groups, in our empirical work we control for time-varying ownership effects. Thus, we use unadjusted labor shares and do not follow the approach in Hsieh and Klenow (2009) and Brandt, Van Biesebroeck, and Zhang (2012) who inflate wage payments so that the aggregated firm-level labor share values are consistent with the values from the national accounts.

The aggregate labor share in the entire sample declined 8.2-percentage points, and this decline is sharpest in 75th percentile (a 13.3-percentage point decline) and smallest in the 25th percentile (a 3.3-percentage point decline). The aggregate labor share in the balanced sample declined 7.1-percentage points, which is slightly less than the 8.2-percentage point decline in the entire sample. And, the declines in the 25th, 50th, and 75th percentiles range from 2.5 to 3.0-percentage points.

For the rest of the paper, we use the balanced sample and focus on changes in labor shares within firms that operate throughout 1999-2006. As a first pass for understanding the decline in aggregate labor shares, we conduct a standard between-within accounting of labor shares at the firm level. Between effects—the changes in the composition of the firm in terms of value added—account for a 3.0-percentage point decline, which is more than 40 percent of the overall 7.1-percentage point decline. It is notable that most of the between changes stem from the composition changes between foreign and domestic private firms: foreign firms that pay higher labor shares in 2006 (on average 0.215 for foreign firms versus 0.208 for all firms) lost value added shares, whereas private firms that pay lower labor shares in 2006 (on average 0.154 for private firms versus 0.208 for all firms) gained value added shares. Within effects—the changes in labor shares within each firm—account for a 4.1-percentage point decline. Surprisingly, almost all of the within changes stem from the firms that were state-owned in 1999 (a 3.9-percentage point decline of the 4.1-percentage point decline), and we discuss this trend more in section 5.

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4Table A.1 in the online appendix contains the summary statistics of labor shares.
5See Appendix I in the online appendix for the accounting method and Table A.2 for the results.
6Throughout the paper, we categorize firms into SOEs, foreign, and domestic private firms according to the ownership in the initial year (1999).
3 Theoretical Considerations

In this section, we take the model in Azmat et al. (2012) and Autor et al. (2017) and include a flexible elasticity of substitution between capital and labor. The structural parameters of the model can be estimated and used for a decomposition analysis of how the capital-labor substitution mechanism can shape the evolving distribution of labor’s share. In this economy, there is a firm in sector $s$ in period $t$ that uses a sector-specific constant returns to scale production function that converts augmented labor ($L_{it}$),\(^7\) the real stock of physical capital ($K_{it}$), and real spending on materials ($M_{it}$) into a real output ($Q_{it}$):

\[
Q_{it} = \omega_{it} \left[ a_s (L_{it})^{\frac{\sigma_s - 1}{\sigma_s}} + (1 - a_s) (K_{it})^{\frac{\sigma_s - 1}{\sigma_s}} \right]^{\frac{\sigma_s a_s}{\sigma_s - 1}} (M_{it})^{1 - \alpha_s} .
\] (2)

Each firm is differentiated by its productivity, $\omega_{it}$. The parameters of the sector-level production function include a weight on labor versus capital in factor inputs, $a_s$, where $0 < a_s < 1$; the sector-specific elasticity of substitution between capital and labor, $\sigma_s$, where $0 \leq \sigma_s < +\infty$; and the relative weight between the factor inputs and intermediate inputs, $\alpha_s$, where $0 < \alpha_s < 1$. Each firm $i$ in each time period $t$ sets a markup ($\mu_{it}$), which is the ratio of the final product price ($p_{it}$) to the marginal cost of producing $Q_{it}$. Input prices for labor, capital, and materials are exogenous variables for firms, and, are denoted, $w_{it}$, $r_{it}$, and $\bar{p}_{it}$, respectively. Note that firms may face different costs of capital and labor (e.g., Hsieh and Klenow, 2009; Brandt et al., 2013). A firm $i$ in sector $s$ in period $t$ chooses inputs ($L_{it}$, $K_{it}$, and $M_{it}$) in order to maximize its profits:

\[
\Pi_{it} = p_{it} Q_{it} - w_{it} L_{it} - r_{it} K_{it} - \bar{p}_{it} M_{it} .
\] (3)

Combining the first order conditions with respect to labor and capital, firm-level capital intensity can be written as:

\[
k_{it} = \left( \frac{r_{it}}{w_{it}} \frac{a_s}{1 - a_s} \right)^{-\sigma_s} .
\] (4)

\(^7\)Our measure of labor equals the head count of employees multiplied by the differences in human capital across China’s four regions. The results do not change even if we simply use the head count of employees.
where $k_{it} = K_{it}/L_{it}$.

By inspection of equation (4), a one-percent decline in the relative cost of capital to labor ($r_{it}/w_{it}$) will cause firms to increase capital intensity by $\sigma_s$ percent.

Using the first order condition for materials, we can obtain an empirical expression for markups:

$$\mu_{it} = \frac{(1 - \alpha_s)}{m_{it}}$$

where the revenue share of intermediate input is $m_{it} = \tilde{p}_{it}M_{it}/p_{it}Q_{it}$.

Finally, using the first order conditions for the three inputs and the relationship between revenue and value added, a firm’s labor share, $s_{it}$, can be written as a function of capital intensities ($k_{it}$) and markups ($\mu_{it}$):

$$s_{it} = \frac{e_s(k_{it})}{\mu_{it} - 1 + \alpha_s}$$ (6)

where

$$e_s(k_{it}) = \frac{\partial Q_{it}/Q_{it}}{\partial N_{it}/N_{it}} = \alpha_s \left[ 1 + \left( \frac{1 - \alpha_s}{\alpha_s} \right) (k_{it})^{\alpha_s - 1} \right]^{-1}.$$ (7)

The system of equations (6) and (7) operationalizes the Piketty and Karabarbounis-Neiman capital-labor substitution mechanism at the firm level: if the elasticity of substitution between capital and labor exceeds unity ($\sigma_s > 1$), an increase in the capital intensity, $k_{it}$ (i.e., a decline in $r_{it}/w_{it}$) causes a firm to cut its payments to labor as a share of value added because it weakens the output elasticity of labor in equation (6). Azmat et al. (2012) and Autor et al. (2017) use a similar system of equations to show how an increase in product markups causes labor shares to decline. Berkowitz et al. (2017) use a variation of this system that includes an explicit political pressure parameter on SOEs to hire excess labor to make predictions about firm-level profitability.

4 Empirical Strategy

In order to conduct a counter-factual analysis, we use the parameter estimates from Berkowitz et al. (2017) who estimated equation (2) using the generalized method of moments (GMM) procedure from De Loecker and Warzynski (2012). Their method is ideal for our empirical exercise because
recent methods for estimating the elasticity of substitution between capital and labor developed by Chirinko et al (2011), Karabarbounis and Neiman (2014), and Oberfield and Raval (2014) are unable to identify some parameters in production functions (e.g., $\alpha_s$ and $a_s$) that we need for our counter-factual analysis.

Berkowitz et al. (2017) estimated equation (2) for each of the 136 3-digit sectors. The estimated weights on factor inputs ($\hat{a}_s$) and labor relative to capital ($\hat{a}_s$) are on average 0.169 and 0.548; and the elasticity of substitution between labor and capital ($\hat{\sigma}_s$) exceeds unity for 130 out of 136 sectors and on average is 1.553, which is larger than the previous microeconometric estimates from advanced countries (see Acemoglu, 2003, p.3 Footnote 3).\(^8\)

4.1 Markups and Capital Intensities

In order to calculate predicted values of labor shares, the estimated production function parameters for each of the 136 3-digit sectors, as well as the observed values of capital intensities ($k_{it}$) and the estimated values of product markups ($\mu_{it}$), are inserted into equations (6) and (7). Because the firm-level values of capital intensities and markups are volatile, we use the three-year moving average values for capital intensities ($\bar{k}_{it}$) and the revenue shares of intermediate inputs to obtain markups ($\bar{\mu}_{it}$)

Figure 2 illustrates that the probability density functions both of capital intensities and product markups shifted to the right during 1999-2006. The 25th, 50th, and 75th percentile values of capital intensities increased by 29.0%, 27.9%, and 28.0%, respectively, suggesting that capital intensities increased almost uniformly across different percentiles of the distribution. The results are similar for product markups: the 25th, 50th, and 75th percentile values of markups increased by 1.1%, 1.5%, and 1.5%, respectively.\(^9\)

4.2 Heterogeneity in Labor Shares

In this sub-section, we show accounting for firm-level heterogeneity is critical for understanding the distribution of labor shares. The theoretical predictions of our model are illustrated using firms in the synthetic fabrics sector in 2006, which is representative of the Chinese manufacturing sector because its elasticity of substitution is close to the cross-sector median value ($\hat{\sigma}_{\text{synthetic fabrics}} = \ldots$)

\(^8\)A detailed discussion of the estimation method is contained in Appendix II of the online appendix.

\(^9\)Table A.3 in the online appendix contains the summary statistics of capital intensities and product markups.
$1.476 < \hat{\sigma}_{median} = 1.489$) and its estimated weight on factor inputs is close to the cross-sector median value ($\hat{\alpha}_{synthetic\ fabrics} = 0.171 > \hat{\alpha}_{median} = 0.163$). In the first panel in Figure 3, the estimated parameters for production functions ($\hat{\sigma}_s$, $\hat{\alpha}_s$ and $\hat{\alpha}_s$), a median value for product markups, and the reported firm-level capital intensities are plugged into equations (6) and (7) to calculate the predicted values of labor shares as a function of capital intensities. Similarly, in the second panel, we use the estimated production parameters, a median value of capital intensities, and the estimated firm-level markups are used to calculate the predicted values of labor shares as a function of product markups.

Consistent with our theoretical model, Figure 3 illustrates that labor shares are decreasing in capital intensities and product markups. While the predicted labor shares in the first panel are clustered in the narrow range of 0.55-0.65, those in the second panel are scattered in the wide range of 0.3-1.0. Our results suggest that the substantial heterogeneity in labor shares (see Figure 1) stems mainly from the markup distribution. Since the production parameters are constant over time, our results also suggest that declining trends in labor shares are not sensitive to large changes in capital intensities, but are very sensitive to small changes in product markups. As we will show in the next section, a 27.9% increase in the median value of capital intensities has a smaller impact on labor’s shares than a 1.5% increase in that of product markups. The sensitivity of labor shares in terms of markups is not surprising because the Chinese manufacturing sector uses production technology that is intensive in intermediate inputs (i.e., the median value of the estimated material’s share, $1 - \hat{\alpha}_s$ is 0.837).\footnote{\textsuperscript{10}The first derivative of equation (6) with respect to markup leads to the following equation:

$$\frac{\partial s_{it}}{\partial \mu_{it}}/\mu_{it} = \frac{-\mu_{it}}{\mu_{it} - (1 - \alpha_s)}.$$}

\footnote{\textsuperscript{10}The first derivative of equation (6) with respect to markup leads to the following equation:

$$\frac{\partial s_{it}}{\partial \mu_{it}}/\mu_{it} = \frac{-\mu_{it}}{\mu_{it} - (1 - \alpha_s)}.$$}

For example, when $1-\alpha_s = 0.8$ and $\mu_{it} = 1$, $(\partial s_{it}/s_{it})/(\partial \mu_{it}/\mu_{it}) = -5$. In general, any small change in product markups could have a major impact on labor shares when markups are close to unity.

5 Counter-factual Analysis

5.1 Predicted Distributions

As previously discussed, SOEs account for 3.9-percentage points of the 4.1-percentage point decline in the within changes of labor shares. The decline in labor protections where SOEs that previously provided job security laid off workers starting the mid-1990s (e.g. Cooper et al., 2015; Berkowitz
et al., 2017) is a potential explanation why SOEs are so important for declining aggregate labor shares. Another potential explanation is that equity pay schemes became more important in SOEs that were either privatized or corporatized. Thus, some of the manager income reported as labor income in pre-corporatization SOEs or pre-privatization SOEs became capital income after these SOEs were corporatized or privatized and this change in income accounting can lower reported labor shares in SOEs.

There are 28,220 firms in the data. Using equations (6) and (7), our theory predicts well the mean values of labor shares for foreign firms. For example, the mean value of actual labor shares in 1999 is 0.411 for foreign firms, whereas that of predicted labor shares in 1999 is 0.440. However, the theory over-predicts labor shares for private domestic firms by 12.5-percentage points in 1999 and by 10.6-percentage points in 2006. As we have argued, we expect that the mean value of actual labor shares in 1999 for SOEs should be greater than that of predicted labor shares in 1999 because we do not take account of the labor protections and the pay scheme prior to corporatization or privatization. Indeed, the theory under-predicts labor shares for SOEs by 9.4-percentage points in 1999 but only by 1.4-percentage points in 2006. Thus, there are ownership-specific differences in pay schemes, labor protections, and other factors that can affect disparities between the actual and predicted labor shares. In order to account for these ownership-specific differences, we adjust predicted labor shares by their ownership-specific mean differences and use the following equation:

$$s_{it} = \frac{e_s(k_{it})}{\bar{\mu}_{it} - 1 + \alpha_s} + s_{jt}$$

(8)

where $s_{jt} = (1/N_{jt}) \left[ \sum_{i \in j} \frac{w_i L_{it}}{V A_{it}} - \sum_{i \in j} \frac{e_i(k_{it})}{\bar{\mu}_{it} - 1 + \alpha_s} \right]$, and $N_{jt}$ is the number of firms in the ownership group $j$ from SOEs, foreign, or domestic private firms.

Equation (8) shows that predicted labor shares vary across firms over time due to capital intensities ($\bar{k}_{it}$), product markups ($\bar{\mu}_{it}$), and ownership-specific factors ($s_{jt}$). Capital intensity ($\bar{k}_{it}$) and product markup ($\bar{\mu}_{it}$) are firm-specific factors, whereas the ownership-specific factor ($s_{jt}$) varies only by a firm’s ownership status in 1999. After eliminating some outlier values, we have 27,937 (27,938) in 1998 (2007) for predicted labor shares from equation (8).\(^{11}\)

\(^{11}\)In Table A.4 in the online appendix, we report the summary statistics of actual and predicted labor shares in 1999 and 2006 by the ownership categories in 1999.
5.2 Counter-factual Analysis

In order to conduct a counter-factual analysis, we need to isolate the contribution of the changes in capital intensities, product markups, and ownership-specific factors. Thus, four models are prepared, of which the first (Model 1) uses labor shares predicted from equation (8) in 1999, whereas the last (Model 4) uses labor shares predicted from equation (8) in 2006.

Specifically, Model 1 is the predicted distribution of labor shares from the balanced sample using the 1999 values of firm-level capital intensities and markups, and ownership-specific factors. Model 2 is obtained by replacing the 1999 values of capital intensities in Model 1 with the 2006 values. And, by moving from Model 1 to Model 2, we simulate the counter-factual impact of the capital-labor substitution. Note that this channel focuses on how the changes in the relative costs of capital to labor drive down labor shares at the firm level. Model 3 is then obtained by taking out the 1999 markups in Model 2 and replacing them with the 2006 markups. And, the difference between Model 3 and Model 2 is the simulated impact of the changes in product markups. Finally, Model 4 is obtained by taking out the 1999 ownership-specific factors in Model 3 and replacing them with the 2006 ownership-specific factors. And, the difference between Model 4 and Model 3 is the simulated impact of the ownership-specific changes in labor shares.\(^{12}\)

During 1999-2006, capital intensities increased (indicating the costs of capital relative to labor fell) and the capital-labor substitution elasticity generally exceeded unity; moreover, product markups increased, SOE accounting procedures for paying labor changed, and SOEs were under less political pressures to hire excess labor. Thus, consistent with our theory, Figure 4 illustrates that the counter-factual distribution of labor shares shifts to the left when the 1999 values of capital intensities, product markups, and ownership-specific factors are replaced, one by one, with the 2006 values.

In Table 1, we report the differences between Models 1 and 2 (the capital-labor substitution channel), between Models 2 and 3 (the product markup channel), and between Models 3 and 4 (the ownership channel) at the different quantiles. We provide standard errors using the conditional and unconditional quantile regressions proposed by Koenker and Bassett (1978) and Firpo et al (2009):

\[
PLS_q^m = PLS_q^{m'} + \beta^m(q) \tag{9}
\]

\(^{12}\)Our results are robust even if we change the order of the models.
where $PLS_q^m (PLS_q^{m'})$ is the $q$th quantile value of the predicted labor share for $m$th ($m'$th) model from Models 1 through 4, and $\beta^m(q)$ is the actual difference in predicted labor shares between the two models. The standard errors are bootstrapped with 100 replications.

Because the conditional and unconditional estimates and standard errors are quite similar, we present the conditional results. The largest contributor to declining labor shares is increasing markups at the 75th percentile, which accounts for a 3-percentage point drop in labor shares. By inspection, the capital-labor substitution channel accounts for between 0.8 to 1.1-percentage point declines in labor shares in the 25th, 50th, and 75th percentiles. Overall, the contribution of markups is quantitatively strong throughout the cumulative distribution relative to the contributions of the capital-labor substitution and ownership factors. The simple OLS results in Table 1 also show that the capital-labor substitution mechanism explains only a 1.2-percentage point of the overall 7.1-percentage point decline in labor shares. The results are consistent even if we use much finer quantiles of the labor share distribution.

To understand what part of declining aggregate labor shares our theory can explain, we apply the between-within accounting to predicted labor shares. Overall, our theory predicts well for the within changes in aggregate labor shares by ownership categories. For example, the within changes from predicted labor shares are almost identical to those from actual labor shares for all types of ownerships (for SOEs, a 3.7-percentage point decline from predicted labor shares versus a 3.9-percentage point decline from actual labor shares; for domestic private firms, a 0.8-percentage point decline from predicted labor shares versus a 0.8-percentage point decline from actual labor shares; and, for foreign firms, a 1.2-percentage point increase from predicted labor shares versus a 0.7-percentage point increase from actual labor shares). However, we cannot explain the total between changes (a 0.4-percentage point decline from predicted labor shares versus a 3.0-percentage point decline from actual labor shares) because our theory only can account for the changes within each firm.

6 Conclusions

Using data from China’s manufacturing sector, we found that labor shares vary substantially across firms due to cross-firm differences in capital intensities, product markups, and ownerships. Although

\footnote{See Table A.5 in the online appendix.}
capital and labor were substitutes, and the costs of capital relative to labor fell, our counter-factual analysis showed that the impact of the capital-labor substitution mechanism on the decline in aggregate labor shares is quite small, accounting for only a 1-percentage point of an overall 7.1-percentage point actual decline over the period of 1999-2006. Factors that cannot be captured in aggregate data including the firm-level distribution of markups, the composition of firms, and the changes in ownership play substantial roles.

Online Appendix

Appendix I: The Between-Within Accounting

In order to get some understanding for the link between the decline in labor shares and the composition of firms, the change in aggregate labor shares is decomposed into its between and within changes. The equation used for this decomposition accounting is

$$\Delta s = \sum_i \Delta v_i \tilde{s}_i + \sum_i \Delta s_i \tilde{v}_i. \quad (10)$$

In equation (10), the change in aggregate labor shares during 1999 to 2006 (i.e., -7.1 percentage points) is $\Delta s = s_{2006} - s_{1999}$ where $s_{2006}$ and $s_{1999}$ are the labor shares from the balanced sample in the manufacturing sector. We also define the following four variables: (1) the change in labor share within firm $i$ is $\Delta s_i = s_{i,2006} - s_{i,1999}$ where $s_{i,2006}$ and $s_{i,1999}$ are the labor share for firm $i$ in 1999 and 2006, (2) the change in the share in value added for firm $i$ is $\Delta v_i = v_{i,2006} - v_{i,1999}$ where $v_{i,2006}$ and $v_{i,1999}$ are the shares of firm $i$ in value added in 1999 and 2006, (3) the average labor share for firm $i$ at 1999 and 2006 is $\bar{s}_i = 0.5(s_{i,2006} + s_{i,1999})$, and (4) firm $i$’s average share in value added is $\bar{v}_i = 0.5(v_{i,2006} + v_{i,1999})$. In equation (10), the first term in the right-hand side is the between change, which captures the change associated with the share of each firm in value added. The second term is the within change because it measures the change in the labor share within each firm $i$. In Table A.2, we report the between and within changes by the ownership status in 1999. For example, the between change is divided into the three ownership categories in year 1999:
\[ \sum_i \Delta v_i s_i = \sum_j \sum_i \Delta v_i s_i \]

where \( j \) is firm \( i \)'s ownership status, SOE, domestic private firm, or foreign firm.

**Appendix II: Production Function Estimation**

We report the complete discussion of the estimation method and robustness checks in Berkowitz et al. (2017). The paper follows an approach proposed by De Loecker and Warzynski (2012) and obtains the production function parameters \((\hat{\sigma}_s, \hat{\alpha}_s, \hat{a}_s)\) for the 136 3-digit sectors.

To estimate the production function in equation (2), we use the timing assumption in Ackerberg et al. (2015) that firms need more time to optimize labor and install capital than purchase intermediate inputs. It follows from this timing assumption that a firm’s demand for intermediate inputs depends on its productivity and the predetermined amounts of labor and the current stock of capital. We also follow De Loecker and Warzynski (2012) and assume that the status of export, which is approximated by an exporter dummy \((D_{it})\), is essential for the choice of intermediate inputs:

\[
\ln(M_{it}) = h_t [\ln(\omega_{it}), \ln(L_{it}), \ln(K_{it}), D_{it}] .
\]

Following Ackerberg et al. (2015), we assume the above equation can be inverted:

\[
\ln(\omega_{it}) = h_t^{-1} [\ln(L_{it}), \ln(K_{it}), \ln(M_{it}), D_{it}] .
\]

We then approximate \(\ln(Q_{it})\) with the second-order polynomial function of the three inputs and that interacted with an exporter dummy:

\[
\ln(Q_{it}) \approx \Phi_t [\ln(L_{it}), \ln(K_{it}), \ln(M_{it}), D_{it}] + \epsilon_{it}
\]  

(11)

where the variables \(Q_{it}\) and \(M_{it}\) are deflated with sector-level output and input deflators from Brandt et al. (2012) and, the real capital stock series is constructed using the perpetual inventory method.
As argued in Gorodnichenko (2007), the sector-level output deflator does not necessarily provide a perfect measure of the output price since firms in the same sector often charge very different prices and enjoy different markups. Thus, ideally real output would be obtained by deflating revenues with a firm-level deflator as in De Loecker et al (2016). Alternatively, since we do not have reliable firm-level deflators, we use Proposition 1 in Gorodnichenko (2007) and verify not only two critical assumptions underlying our theory (constant returns to scale in production and competitive factor markets) but also our estimates of markups.

Next, we obtain the predicted value of equation (11), \( \hat{\lambda}_t \), and compute the corresponding value of productivity for any combination of parameters \( \Omega = (\bar{a}_s, \bar{\sigma}_s, \bar{a}_s) \). This enables us to express the log of productivity \( \ln(\tilde{\omega}_{it}(\Omega)) \) as the predicted log output minus the logged contribution of three inputs:

\[
\ln(\tilde{\omega}_{it}(\Omega)) = \hat{\lambda}_t - \frac{\bar{a}_s \bar{\sigma}_s}{\bar{\sigma}_s - 1} \ln \left[ \bar{\sigma}_s (L_{it})^{\frac{\bar{a}_s - 1}{\bar{\sigma}_s}} + (1 - \bar{a}_s) (K_{it})^{\frac{\bar{a}_s - 1}{\bar{\sigma}_s}} \right] - (1 - \bar{a}_s) \ln(M_{it}).
\]

Our generalized method of moments (GMM) procedure assumes that firm-level innovations to productivity, \( \zeta_{it}(\Omega) \), do not correlate with the predetermined choices of inputs. To recover \( \zeta_{it}(\Omega) \), we assume that productivity for any set of parameters, \( \tilde{\omega}_{it}(\Omega) \), follows a non-parametric first order Markov process, and then we can approximate the productivity process with the third order polynomial:

\[
\ln(\tilde{\omega}_{it}(\Omega)) = \gamma_0 + \gamma_1 \ln(\tilde{\omega}_{i,t-1}(\Omega)) + \gamma_2 [\ln(\tilde{\omega}_{i,t-1}(\Omega))]^2 + \gamma_3 [\ln(\tilde{\omega}_{i,t-1}(\Omega))]^3 + \zeta_{it}(\Omega).
\]

From this third order polynomial, we can recover the innovation to productivity, \( \zeta_{it}(\Omega) \), for a given set of the parameters. Since the productivity term, \( \ln(\tilde{\omega}_{it}(\Omega)) \), can be correlated with the current choices of flexible inputs, \( \ln(L_{it}) \) and \( \ln(M_{it}) \), but it is not correlated with the predetermined variable, \( \ln(K_{it}) \), the innovation to productivity, \( \zeta_{it}(\Omega) \), will not be correlated with \( \ln(K_{it}) \), \( \ln(L_{i,t-1}) \), and \( \ln(M_{i,t-1}) \). Thus, we use the moment condition similar to De Loecker and Warzynski.
\[ m_s(\Omega) \equiv E \left[ \zeta_{it}(\Omega) \begin{pmatrix} \ln(K_{it}) \\ \ln(L_{i,t-1}) \\ \ln(K_{it}) \ln(L_{i,t-1}) \\ [\ln(K_{it})]^2 \\ [\ln(L_{i,t-1})]^2 \\ \ln(M_{i,t-1}) \end{pmatrix} \right] = 0 \]  

(12)

and search for the optimal combination of \( \hat{\alpha}_s, \hat{\sigma}_s, \) and \( \hat{\sigma}_s \) by minimizing the sum of the moments (and driving it as close as possible to zero) using the standard weighting procedure for plausible values of \( \Omega \).

References


Notes: (1) We report the probability density for the balanced sample. (2) We drop the top and bottom 0.25% of the balanced sample for each year.

Notes: (1) We report the probability density for the balanced sample. (2) To obtain the stable values, we use the moving average values of capital intensities and intermediate shares to calculate 1999 and 2006 values of capital intensities and markups. (3) We drop the top and bottom 0.25% of the balanced sample for each year.
Notes: (1) We obtained the predicted labor shares for all continuer firms in the sector in 2006 using the estimated production parameters, the reported capital intensity, and the median value of markups (1.022) for the first panel. (2) We obtained the predicted labor shares for all continuer firms in the sector in 2006 using the estimated production parameters, the median value of capital intensity (1.222), and the estimated values of markups for the second panel.

Notes: (1) We drop the top and bottom 0.25% of the balanced sample for each model. (2) Model 1 uses the predicted values of labor shares using the 1999 values of capital intensities, markups, and ownership factors; Model 2 uses the 1999 values of markups and ownership factors, and the 2006 values of capital intensities; Model 3 uses the 2006 values of capital intensities and markups, and the 1999 values of ownership factors. Finally, Model 4 uses the 2006 values of capital intensities, markups, and ownership factors.
<table>
<thead>
<tr>
<th></th>
<th>Model 1 to 2 (capital intensities)</th>
<th>Model 2 to 3 (markups)</th>
<th>Model 3 to 4 (ownership)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary least squares</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean effect</td>
<td>-0.012***</td>
<td>-0.022***</td>
<td>0.002</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(0.001)</td>
<td>(0.005)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Quantile regression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25th percentile</td>
<td>-0.008***</td>
<td>-0.011***</td>
<td>0.001</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>50th percentile</td>
<td>-0.007***</td>
<td>-0.021***</td>
<td>-0.006***</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>75th percentile</td>
<td>-0.011***</td>
<td>-0.030***</td>
<td>-0.007*</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
</tbody>
</table>

Notes: (1) Bootstrap standard errors are in the parentheses. (2) ***, **, and * indicate that changes in labor shares are statistically different from zeros at the 1%, 5%, and 10% confidence levels.
Online Appendix

Table A.1: Summary statistics of labor shares

<table>
<thead>
<tr>
<th></th>
<th>Entire sample</th>
<th>Balanced sample</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor shares</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25th percentile</td>
<td>0.171</td>
<td>0.133</td>
<td>-0.038</td>
<td>0.164</td>
<td>0.139</td>
<td>-0.025</td>
</tr>
<tr>
<td>50th percentile</td>
<td>0.348</td>
<td>0.276</td>
<td>-0.072</td>
<td>0.301</td>
<td>0.272</td>
<td>-0.030</td>
</tr>
<tr>
<td>75th percentile</td>
<td>0.629</td>
<td>0.496</td>
<td>-0.133</td>
<td>0.489</td>
<td>0.464</td>
<td>-0.025</td>
</tr>
<tr>
<td>Aggregate average</td>
<td>0.292</td>
<td>0.210</td>
<td>-0.082</td>
<td>0.252</td>
<td>0.182</td>
<td>-0.071</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.794</td>
<td>0.429</td>
<td>-0.365</td>
<td>0.378</td>
<td>0.348</td>
<td>-0.030</td>
</tr>
<tr>
<td>Value added</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¥ (billions)</td>
<td>1,472</td>
<td>5,729</td>
<td>289.3%</td>
<td>645</td>
<td>1,978</td>
<td>206.7%</td>
</tr>
<tr>
<td>Share to entire sample</td>
<td>1.000</td>
<td>1.000</td>
<td>-</td>
<td>0.438</td>
<td>0.345</td>
<td>-21.2%</td>
</tr>
<tr>
<td>Observations</td>
<td>117163</td>
<td>237059</td>
<td>102.3%</td>
<td>28220</td>
<td>28220</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: (1) We drop the top and bottom 0.25% of the entire or balanced sample for each year. (2) “change” for labor shares is the percentage point change over 1999-2006. Otherwise, it is the percentage change.

Table A.2: Firm-level between-within decomposition by the ownership status in 1999

<table>
<thead>
<tr>
<th></th>
<th>Decomposition</th>
<th>Aggregate labor share</th>
<th>Value added share</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Between</td>
<td>Within</td>
<td>1999</td>
<td>2006</td>
<td>1999</td>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>SOEs</td>
<td>-0.007</td>
<td>-0.039</td>
<td>0.294</td>
<td>0.182</td>
<td>0.432</td>
<td>0.442</td>
<td></td>
</tr>
<tr>
<td>Private firms</td>
<td>-0.002</td>
<td>-0.008</td>
<td>0.213</td>
<td>0.154</td>
<td>0.285</td>
<td>0.329</td>
<td></td>
</tr>
<tr>
<td>Foreign firms</td>
<td>-0.021</td>
<td>0.007</td>
<td>0.224</td>
<td>0.215</td>
<td>0.283</td>
<td>0.229</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-0.030</td>
<td>-0.041</td>
<td>0.309</td>
<td>0.208</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>
Table A.3: Summary statistics of capital intensities and markups

<table>
<thead>
<tr>
<th></th>
<th>Capital intensities</th>
<th>Markups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1999</td>
<td>2006</td>
</tr>
<tr>
<td>25th percentile</td>
<td>0.231</td>
<td>0.298</td>
</tr>
<tr>
<td>50th percentile</td>
<td>0.437</td>
<td>0.559</td>
</tr>
<tr>
<td>75th percentile</td>
<td>0.807</td>
<td>1.034</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.887</td>
<td>0.929</td>
</tr>
</tbody>
</table>

Table A.4: Actual and fitted labor shares by ownership status in 1999

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SOEs</td>
<td>0.500</td>
<td>0.406</td>
<td>0.094</td>
<td>0.410</td>
<td>0.396</td>
<td>0.014</td>
</tr>
<tr>
<td>Private firms</td>
<td>0.329</td>
<td>0.453</td>
<td>-0.125</td>
<td>0.301</td>
<td>0.407</td>
<td>-0.106</td>
</tr>
<tr>
<td>Foreign firms</td>
<td>0.411</td>
<td>0.440</td>
<td>-0.029</td>
<td>0.429</td>
<td>0.413</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Table A.5: Firm-level between-within decomposition for predicted labor shares

<table>
<thead>
<tr>
<th></th>
<th>Actual labor shares</th>
<th>Predicted labor shares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Between</td>
<td>Within</td>
</tr>
<tr>
<td>SOEs</td>
<td>-0.007</td>
<td>-0.039</td>
</tr>
<tr>
<td>Private firms</td>
<td>-0.002</td>
<td>-0.008</td>
</tr>
<tr>
<td>Foreign firms</td>
<td>-0.021</td>
<td>0.007</td>
</tr>
<tr>
<td>Total</td>
<td>-0.030</td>
<td>-0.041</td>
</tr>
</tbody>
</table>