# Latent Changes in the Labor Share

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Acemoglu and Restrepo (2019)'s canonical model of automation unambiguously predicts a decline in the labor share within sectors. Decomposing changes in the US labor share into within-sector and between-sector components, they show that within-sector changes indeed account for the bulk of the recent decline in the US labor share, while overall between-sector changes are quantitatively unimportant. However, by extending their single-sector framework to a multi-sector model and rooting it in an empirically tractable decomposition, this paper shows that the small overall between-sector component conceals substantial, though offsetting, equilibrium changes in consumer demand resulting from sector-specific changes in factor quantities and TFP growth. Although these equilibrium forces have not impacted overall between-sector changes in the US labor share so far, their importance indicates that ever-declining labor shares due to technological progress, such as AI, are not inevitable in the future.

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# 1. Introduction

The labor share is the fraction of aggregate income accruing to workers rather than to capital owners. At least since the Industrial Revolution, the labor share has always fascinated and often puzzled economists and policymakers. Already in *The Wealth of Nations*, Smith (1776) noted that aggregate output could be decomposed into shares that accrue to the various "original sources", one of which being labor, and that the distribution of national income to wages, rents, and profits is closely associated with inequality in a society's standards of living. Keynes (1939) noticed that Western economies had a stable labor share between the 1910s and the 1930s and claimed this was "a bit of a miracle." Kaldor (1957) argued that the stability of the labor share is an important stylized fact of balanced economic growth. However, Solow (1958) was skeptical, arguing that this constancy "may be an optical illusion" and that we should not view the labor share as a fundamental constant of economics.

More recently, a literature has emerged examining the notable decline in the labor share in the US and other advanced economies over the last few decades. Examining its causes, many studies have focused on different possible forces: technological progress, an increased use of imported intermediate inputs that more easily substitute for domestic labor than for capital, the rise of superstar firms and profits, and a shift in the balance of power in industrial relations toward employers and away from workers.[1] Reviewing more than 12,000 studies, Grossman and Oberfield (2022) conclude that we still do not have a firm grip on why the labor share has fallen recently.

Part of our lack of a better understanding is that the literature has so far focused on many proximate but few primitive causes for the recent decline in the labor share. As a result, studies present different sides of the same coin. Take, for example, technological progress as a primitive driver. Automation can directly substitute capital for labor. However, if it disproportionately benefits larger firms, it can also lead to rising

[1]Papers that provide evidence for automation as an explanation for the decline in the labor share include Hubmer and Restrepo (2026); Karabarbounis (2024); Harrison (2024); Moll, Rachel, and Restrepo (2022); Bergholt, Furlanetto, and Maffei-Faccioli (2022); Acemoglu and Restrepo (2019); Autor et al. (2018). Capital accumulation (a.k.a. investment-specific technological progress) is examined in Karabarbounis and Neiman (2014) and Piketty (2014). The importance of product market power is examined in Autor et al. (2020); Kehrig and Vincent (2021); De Loecker, Eeckhout, and Unger (2020); Gutiérrez and Philippon (2017). Examples of evidence for globalization include Smith et al. (2022); Elsby, Hobijn, and Şahin (2013). Studies pointing to the role of labor market institutions, such as unions and minimum wages, are Ciminelli, Duval, and Furceri (2020); Stansbury and Summers (2020); Bentolila and Saint-Paul (2003); Blanchard and Giavazzi (2003).

concentration and a greater exercise of product and labor market power. Therefore, it will be difficult to distinguish which effects on factor shares work through altered production techniques and which ones work through the mechanism of rising markups and increased profits. Meanwhile, automation could reflect directed innovation, which, in turn, could be a response to union wage rents. Consequently, the automation of union jobs might result in a loss of worker power. In summary, the same primitive cause can move many endogenous variables together.

To illustrate the importance of equilibrium forces underlying the recent decline in the labor share, this paper builds on Acemoglu and Restrepo (2019) who focus on the role of automation as a type of technological progress. Their paper develops a task-based framework in which automation displaces workers from certain tasks required to produce sectoral output, making the sector's production technology more capital-intensive. Consequently, the sector's labor share unambiguously decreases over time. Decomposing changes in the aggregate labor share into within-sector and between-sector components, their paper shows that *within-sector* changes indeed account for the bulk of the recent decline in the US labor share. Acemoglu and Restrepo (2019) do not focus on overall between-sector changes because, they argue, these changes are quantitatively too small to be important.

This paper builds on Acemoglu and Restrepo (2019) by modeling and quantifying the role of sector-specific increases in factor supplies or technological progress in *between-sector* changes in the economy-wide labor share. The paper makes two contributions. First, it extends their canonical single-sector framework to multiple sectors, introducing the long-run price elasticity of consumer demand for sectoral outputs. The key insight is that a sector-specific increase in factor supplies or technological progress (including not only automation but also augmentation or factor-augmenting technological progress) decreases the sector's relative output price and increases sectoral output. Assuming demand is price inelastic, as is realistic in aggregate models, this leads to a decrease in that sector's real revenue and wage bill. The impact on the aggregate labor share—the ratio of the economy's wage bill to revenue—is ambiguous. If that sector's production technology is relatively labor-intensive compared to other sectors, the economy-wide wage bill will decrease by more than the economy-wide revenue, resulting in a decrease in the aggregate labor share. If not, the aggregate labor share increases. To show this more formally, this paper derives a novel decomposition of within-between-sector changes in the aggregate labor share, where the roles of the primitive causes of the between-sector component are specified. Using this novel decomposition, the second contribution of this paper is to empirically show that the relative stability of overall between-sector changes in the US labor share veils substantial, though offsetting, equilibrium changes in consumer demand resulting from sector-specific changes in factor supplies and technological progress.

The remainder of the paper is organized as follows. Section 2 empirically summarizes changes in the US labor share, both within and between sectors. Section 3 presents our multi-sector model, and Section 4 derives a novel decomposition of between-sector changes in the aggregate labor share that is rooted in our model. Section 5 briefly describes the data. Section 6 presents our empirical results, documenting that an overall between-sector change in the US labor share, although quantitatively small, masks substantial sector-specific but countervailing changes in factor quantities and TFP growth rates. Section 7 concludes with a short discussion of the possible impact of future technologies, such as AI, on the labor share.

## 2. Changes in the labor share within and between sectors

Using simple differentiation and first-degree Taylor polynomials, the log change in the economy-wide labor share between periods $t-1$ and $t$ can be decomposed using the following approximation:[2]

(1) $$\Delta \ln(s^L) \approx$$

$$\ln\Big(\sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t}\Big) - \ln\Big(\sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t-1}\Big) \qquad \text{Within-sectors}$$

$$+\ln\Big(\sum_{j=1}^{J} s^L_{j,t-1}\chi_{j,t}\Big) - \ln\Big(\sum_{j=1}^{J} s^L_{j,t-1}\chi_{j,t-1}\Big) \qquad \text{Between-sectors}$$

with $\Delta X \equiv X_t - X_{t-1}$ the change in $X$ between time periods $t-1$ and $t$; $j = 1, \ldots, J$ sectors in the economy; $\chi_{j,t} \equiv P_{j,t}Y_{j,t}/P_tY_t$ the revenue share of sector $j$ in period $t$; $s^L_{j,t} \equiv W_{j,t}L_{j,t}/P_{j,t}Y_{j,t}$ the labor share in sector $j$ in period $t$; and $s^L_t \equiv W_tL_t/P_tY_t$ the economy-wide or aggregate labor share in period $t$. The within-sector component on the right-hand side of equation (1) captures changes in labor shares within sectors over time, while the between-sector component captures changes in the composition of sectoral revenue.

[2]See Appendix A for details.

Panel A of Figure 1 quantifies the decomposition in equation (1) for annual changes in the US labor share for each year between 2000 and 2016.[3] Although annual within-sector changes fluctuated considerably, on average, labor shares decreased over time within sectors. Between-sector changes in the aggregate labor share fluctuated much less and were smaller on average. Panel B of Figure 1 further illustrates these results by plotting the cumulative changes over time for each component. Within-sector changes contributed to a decline in the economy-wide labor share of 6 percentage points between 2000 and 2016, whereas the cumulative between-sector change is much smaller.

The finding that the decrease in the economy-wide US labor share since 2000 is mainly due to decreases in labor shares within sectors is in line with Acemoglu and Restrepo (2019), who attribute these within-sector changes to the adoption of automation technologies. However, if the extent of technological progress differs across sectors and factors of production are mobile between sectors, one would also expect to see changes in sectoral revenue shares and, therefore, perhaps a substantial between sector component too. The remainder of this paper shows that sector-specific technological progress (including automation, the creation of new labor tasks, and factor-augmenting technological progress) and changes in factor quantities are indeed quantitatively important, but also that these underlying drivers have countervailing impacts on the overall between-sector changes in the US labor share and are, therefore, latent.

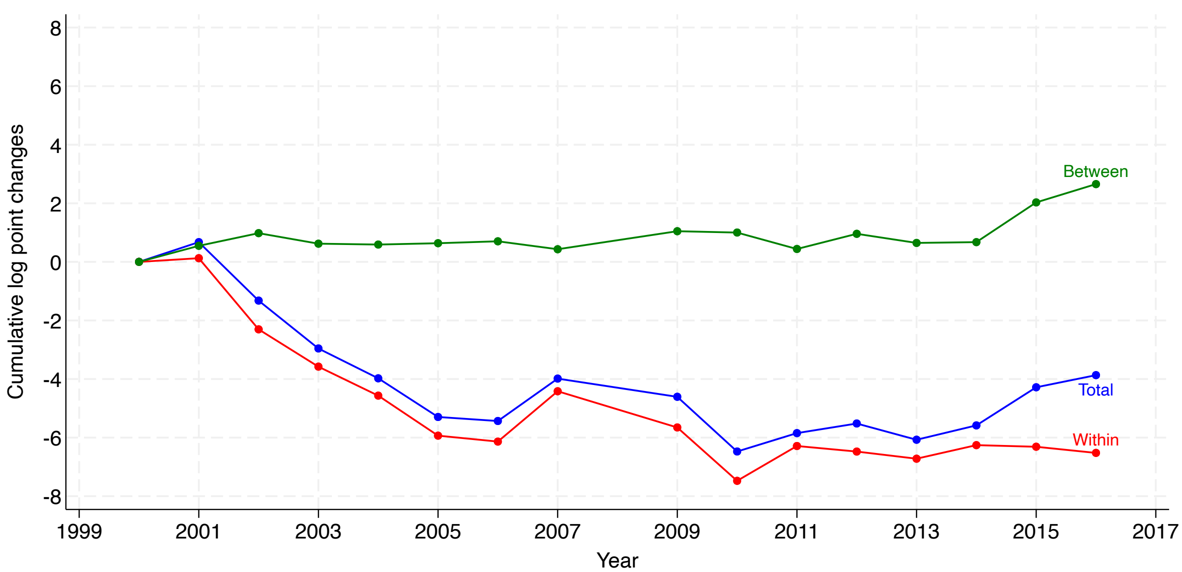
The remainder of this paper first extends the single-sector model in Acemoglu and Restrepo (2019) to a model with multiple sectors producing different consumption goods. The model's equilibrium is presented, and comparative statics for different types of technological progress, labor mobility, and capital accumulation, which are allowed to differ between sectors, are derived. These comparative statics will then be rooted in a novel decomposition of changes in the economy-wide labor share within and between sectors. Importantly, this decomposition will allow us to further decompose the overall between-sector change to quantify the separate impacts of sector-specific changes in factor quantities (i.e., sector-specific changes in physical labor and capital) and TFP growth rates (capturing various types of technological progress).

[3]See Section 5 below for a discussion of the data used in the decomposition.

FIGURE 1. **Changes in the labor share within and between sectors**

A. **Annual changes**


B. **Cumulative annual changes**




**Notes**: Equation (1). Data come from the Bureau of Economic Analysis (BEA) for 61 private-sector industries spanning 2000 to 2017, supplemented by data from the Bureau of Labor Statistics (BLS). See Section 5 for a discussion of data sources.

## 3. A task model of technological progress with multiple sectors

This section extends the basic single-sector task model in Acemoglu and Restrepo (2019) to a model with multiple sectors. It is assumed that a representative consumer combines goods produced by different sectors according to a CES utility function and that each sector produces a single good by combining tasks (done by labor or capital) according to a Cobb-Douglas technology. Given these assumptions, equilibrium expressions for sectoral wage bills and output can be derived.

### 3.1. Consumption

Assume consumers derive utility from consuming goods $Y_1,\ldots,Y_J$ according to the following CES utility function:

$$Y(Y_1,\ldots,Y_J) = \left[\sum_{j=1}^{J} Y_j^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

$$\text{such that } \sum_{j=1}^{J} P_j Y_j = PY$$

with $0 < \sigma < \infty$ the elasticity of substitution between goods in consumption, $P_j$ the price of good $j$, $P$ the ideal price index and $Y$ total utility or real aggregate income.

Given the utility function in equation (2), $P$ is given by:

$$P(P_1,\ldots,P_J) = \left[\sum_{j=1}^{J} P_j^{1-\sigma}\right]^{\frac{1}{1-\sigma}} = 1 \tag{3}$$

$P$ is the minimum expenditure required to purchase one additional unit of utility in equilibrium.[4] Given that preferences are homothetic, $P$ is unique and the last equality in equation (3) follows from choosing consumption as the numeraire.

Multiplying inverse consumer demand, $P_j(Y_j) = [Y/Y_j]^{1/\sigma}$, with $Y_j$ gives an expres-

[4]Note that $\sum_{j=1}^{J} P_j Y_j = PY = e(P_1,\ldots,P_J)Y = E(P_1,\ldots,P_J,Y)$ with $e(P_1,\ldots,P_J)$ the minimum expenditure per unit of utility in equilibrium and $E(P_1,\ldots,P_J,Y)$ the total expenditure function.

sion for sector $j$'s real revenue:

$$P_j Y_j = Y_j^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}} \tag{4}$$

If $Y_j$ increases and $P_j$ decreases following an outward shift in product supply, the impact on sector $j$'s real revenue, $P_j Y_j$, is ambiguous and depends on the elasticity of substitution in consumption, $\sigma$. According to equation (4), $P_j Y_j$ will decrease if and only if $\sigma < 1$. In the extreme case in which consumer demand for $Y_j$ were perfectly inelastic (i.e. $\sigma \to 0$), an outward shift in product supply would result in a decrease in $P_j$ for given $Y_j$. In contrast, if consumer demand were perfectly elastic (that is, $\sigma \to \infty$), an outward shift in product supply would increase $Y_j$ for given $P_j$.

Most estimates of $\sigma$ are well below one. Ravel (2017) surveys more than 50 papers that use estimates of aggregate elasticities of substitution to conclude that they are, on average, well below unity, with only a few papers in the literature providing estimates above one. In our setting, assuming that $\sigma$ is less than unity excludes the possibility that shocks which shift product supply outward, such as technological progress, result in ever increasing sectoral revenue. This self-correcting mechanism also explains why the revenue shares of sectors such as agriculture and manufacturing, which have experienced pervasive technological progress over the last centuries and decades, have been decreasing instead of increasing.

### 3.2. Production

There are $J$ sectors each producing a final good. In each sector $j = 1, 2, ..., J$, the production of $Y_j$ is given by the following Cobb-Douglas production function:

$$Y_j = \exp\left[\int_{N_j-1}^{N_j} \ln(y_j(z))dz\right] \tag{5}$$

with $y_j(z)$ the quantity of task $z$ used in the production of $Y_j$. There is a sector-specific continuum of tasks over a unit-interval such that $z \in [N_j - 1, N_j]$ for given $N_j$.

Each task quantity is produced using capital, $k_j(z)$, or labor, $l_j(z)$, according to:

$$y_j(z) = \begin{cases} A^L \gamma_j^L(z) l_j(z) + A^K \gamma_j^K(z) k_j(z) & \text{if} \quad z \in [N_j - 1, I_j] \\ A^L \gamma_j^L(z) l_j(z) \quad \text{if} \quad z \in (I_j, N_j] \end{cases} \tag{6}$$

with $A^L$ and $A^K$ factor-augmenting technologies common across sectors, and with $\gamma_j^L(z)$ and $\gamma_j^K(z)$ sector-specific task productivity schedules of labor and capital, respectively.

We assume that tasks are ordered on the unit interval such that $\gamma_j^K(z)/\gamma_j^L(z)$ is decreasing in $z$. That is, capital has a comparative advantage in the production of lower-indexed tasks, and labor has a comparative advantage in the production of higher-indexed tasks. Task $I_j \in (N_j - 1, N_j)$ is an exogenous sector-specific task threshold such that all tasks $z \leq I_j$ can be produced by labor or capital (and will be produced by capital in equilibrium), and all tasks $z > I_j$ can only be produced by labor.

Finally, the sector's capital stock, $K_j$, and employment of workers, $L_j$, are given by:

$$\int_{N_j-1}^{N_j} k_j(z)dz = K_j \quad \text{and} \quad \int_{N_j-1}^{N_j} l_j(z)dz = L_j \tag{7}$$

We assume that $K_j$ and $L_j$ are supplied inelastically, but we allow them to change differently across sectors over time. Therefore, the same is true for the economy-wide capital stock and labor force.

### 3.3. Equilibrium

Define $W_j$ as the real consumer wage for workers in sector $j$. That is, $W_j$ is the price of one unit of $l_j(z)$. Sector $j$'s real labor income, $W_jL_j$, in equilibrium is given by:

$$W_jL_j = s^L(I_j, N_j)P_jY_j = [N_j - I_j]P_jY_j \tag{8}$$

where $s^L(I_j, N_j) \equiv W_jL_j/[P_jY_j] = N_j - I_j$ is the labor share in sector $j$.[5] Because it was assumed that tasks are combined Cobb-Douglas to produce output, the labor share in each sector only depends on that sector's fraction of tasks done by workers.

Sector $j$'s equilibrium output, $Y_j$, can be written as:

$$Y_j \equiv \Pi(I_j, N_j)\left[\frac{A^KK_j}{1 - s^L(I_j, N_j)}\right]^{1-s^L(I_j,N_j)}\left[\frac{A^LL_j}{s^L(I_j, N_j)}\right]^{s^L(I_j,N_j)} \tag{9}$$

[5]See Appendix B.1 for a detailed derivation of the model's equilibrium.

with $\Pi(I_j, N_j)$ given by:

$$\Pi(I_j, N_j) \equiv \exp\left[\int_{N_j-1}^{I_j} \ln(\gamma_j^K(z))dz + \int_{I_j}^{N_j} \ln(\gamma_j^L(z))dz\right]$$

which captures the gains from task specialization, given that capital (labor) has a comparative advantage in performing lower-indexed (higher-indexed) tasks.

## 4. Comparative statics

Using the expressions above, this section analyzes equilibrium changes in a sector's real wage bill and the aggregate labor share following various types of technological progress and changes in sector-specific factor supplies.

### 4.1. Changes in real wage bills

Taking the logarithm on both sides of equation (8) and differentiating gives:

$$d\ln(W_j L_j) = \left\{\frac{1}{s^L(I_j, N_j)}[dN_j - dI_j]\right\} + d\ln(P_j Y_j) \tag{10}$$

where the terms in curly brackets capture changes in labor demand conditional on sector $j$'s revenue. In particular, they capture direct displacement and expansion effects because automation, $dI_j$, and the creation of new labor tasks, $dN_j$, result in the reallocation of labor and capital across tasks within sectors.

The last term in equation (10), $d\ln(P_j Y_j)$, captures a change in the revenue of the sector $j$. Using equation (4), this change in sectoral revenue can be written as:

$$d\ln(P_j Y_j) = \frac{\sigma - 1}{\sigma} d\ln(Y_j) + \frac{1}{\sigma} d\ln(Y) \tag{11}$$

where the first term on the right-hand side captures the impact of changes in sectoral output, $d\ln(Y_j)$, and the second term captures the impact of changes in economy-wide income, $d\ln(Y)$.

To further decompose the change in sectoral output, $d\ln(Y_j)$, take logs of equation (9) and differentiate to get:

$$d\ln(Y_j) = \left\{s^L(I_j, N_j) d\ln(L_j) + [1 - s^L(I_j, N_j)] d\ln(K_j)\right\} + d\ln(Y_j)_{|K_j, L_j} \tag{12}$$

where the terms in curly brackets capture factor size effects, and the last term captures sector-specific TFP growth. Factor size effects capture changes in log output following changes in factor supplies $L_j$ and $K_j$ for a given production technology.[6] These changes in $L_j$ and $K_j$ capture changes in the supply of labor and capital that can be sector-specific. Sector-specific TFP growth, $d\ln(Y_j)_{|K_j,L_j}$, captures changes in sectoral output for given $L_j$ and $K_j$. This captures various types of technological progress in the model: automation, the creation of new labor tasks, and factor-augmenting technological progress.[7]

Combining equations (10), (11) and (12) gives:

$$
\begin{aligned}
(13)\qquad & d\ln(W_j L_j) = \\
& [dN_j - dI_j]/s_j^L && \text{Task-reallocation effects} \\
& + \frac{\sigma - 1}{\sigma} \times \begin{cases} s_j^L d\ln(L_j) + [1 - s_j^L] d\ln(K_j) & \text{Factor size effects} \\ + d\ln(Y_j)|K_j, L_j & \text{TFP growth} \end{cases} \\
& + d\ln(Y)/\sigma && \text{Aggregate income effect}
\end{aligned}
$$

with $s_j^L$ the labor share in sector $j$. The task-reallocation effects capture within-sector changes, the factor size effects and TFP growth capture between-sector changes, and aggregate income effects are common across sectors.

The between-sector changes in equation (13), driven by sector-specific factor size effects and TFP growth, capture a substitution effect between goods in consumption. Intuitively, an increase in factor supplies or TFP shifts the sector's product supply curve outward, causing us to move down the sector's downward sloping product demand curve. Consequently, sectoral output increases, and the sector's relative output price decreases. Whether sectoral revenue increases or decreases depends on whether the price elasticity of product demand, $\sigma$, is greater than or less than unity. Our empirical analysis below assumes a value for $\sigma = 0.2$, such that sectoral revenue decreases. Because between-sector changes assume that factor shares are constant over time within-sectors,

[6] The expression for factor size effects follows directly from taking logs of the Cobb-Douglas aggregate in equation (9) and differentiating with respect to $\ln(L_j)$ and $\ln(K_j)$. More generally, Appendix B.2 shows that equation (12) must be true for any production function with constant returns to scale.

[7] See Appendix B.3 for details. The literature also refers to capital accumulation as a type of technological progress, a.k.a. "investment-specific technological progress" that assumes new technologies are embodied in capital investments.

the sectoral wage bill must also decrease.[8]

### 4.2. Changes in the labor share

This subsection uses the decomposition of the sectoral wage bill in equation (13) to derive a decomposition of the economy-wide labor share that is rooted in our structural model.[9] The change in the economy-wide labor share is given by:

$$
\begin{aligned}
(14)\quad \Delta \ln(s^L) = & \sum_{j=1}^{J} l_{j,t-1}[\Delta N_j - \Delta I_j]/s^L_{j,t-1} \qquad \text{Task reallocation effect} \\
& + \frac{\sigma - 1}{\sigma} \sum_{j=1}^{J} [l_{j,t-1} - \chi_{j,t-1}] \times \begin{cases} s^L_{j,t-1}\Delta \ln(L_j) & \text{Labor size effect} \\ +[1 - s^L_{j,t-1}]\Delta \ln(K_j) & \text{Capital size effect} \\ +\Delta \ln(Y_j)|K_j, L_j & \text{TFP growth} \end{cases}
\end{aligned}
$$

with $l_{j,t-1} \equiv W_{j,t-1}L_{j,t-1}/W_{t-1}L_{t-1}$ the wage bill share of sector $j$ in the economy-wide wage bill in period $t-1$; as before, $\chi_{j,t-1}$ is the revenue share of sector $j$ in period $t-1$, and $\sigma$ is the constant long-run price elasticity of product demand.[10]

As in equation (13), the labor size, capital size, and TFP growth effects capture between-sector changes in the aggregate labor share. Intuitively, an increase in a sector's factor supplies or TFP growth rate decreases sectoral revenue if $\sigma < 1$. The between-sector component in equation (13) shows that, for constant factor shares within-sectors, a decrease in sectoral revenue will also decrease that sector's wage bill. What the term in square brackets in equation (14) further shows is that the economy-wide labor share increases or decreases depending on that sector's wage bill share, $l_{j,t-1}$, relative to its revenue share, $\chi_{j,t-1}$. If $l_{j,t-1} > \chi_{j,t-1}$, the aggregate labor share decreases if

[8] Appendix C provides an intuitive analysis of the decomposition in equation (13), including some special cases. For example, it considers the case in which $L_j$ and $K_j$ increase in the same proportion in each sector. In this case, there is only an aggregate income effect, illustrating the assumption of a constant returns to scale economy. Another special case is when technological progress is identical in all sectors. If so, there exists only a common within-sector and an aggregate income effect, there is no between-sector effect, and the analysis effectively simplifies to a one-sector model.

[9] See Appendix D for a formal derivation. In contrast to equation (1) which provides an approximate accounting decomposition of actual changes in the aggregate labor share, the decomposition in this subsection is exact and structural, but only if our model is correct. Because the decomposition in this subsection will be taken to data, changes over time are expressed in discrete time notation.

[10] Assuming a CES instead of a Cobb-Douglas production function in equation (5) would only change the within-sector but not the between-sector component in equation (14). For an expression of the within-sector component assuming a CES production function, see Acemoglu and Restrepo (2019).

factor supplies or TFP growth increase. But if $l_{j,t-1} < \chi_{j,t-1}$, the aggregate labor share increases. If $l_{j,t-1} = \chi_{j,t-1}$, even large shocks in factor supplies or TFP growth have no impact on the economy-wide labor share.

An intuitive interpretation of this result is that an increase in factor supplies or TFP growth in a sector decreases both its real wage bill and revenue by the same percentage because the labor share is assumed to be constant over time within-sectors when quantifying between-sector changes. Because the aggregate labor share is the ratio of the economy-wide wage bill to revenue, the proportionate change in the aggregate labor share depends solely on how labor-intensive that sector is relative to other sectors in the economy. For more labor-intensive sectors, the aggregate wage bill decreases by more than aggregate revenue, such that the economy-wide labor share decreases. For more capital-intensive sectors, the aggregate wage bill decreases by less than aggregate revenue, such that the economy-wide labor share increases.[11]

Consider, for example, healthcare services. US healthcare services have experienced a strong influx of workers (i.e., $\Delta \ln(L_j) > 0$), possibly in part due to automation in other sectors. Consequently, the quantity of healthcare services has increased, but the relative price and real revenue have decreased. Given that the sector's wage bill share is larger than it's revenue share (i.e., $l_j > \chi_j$), or that the sector is relatively labor-intensive compared to other sectors, the aggregate labor share tends to decrease due to a negative between-sector change. Next, consider telecommunications, a capital-intensive sector that has seen rapid capital accumulation and TFP growth due to new ICT technologies (i.e., $\Delta \ln(Y_j)|K_j, L_j > 0$). Consequently, the sector's real revenue and, for a constant labor share within telecommunications, its wage bill have decreased. Given that the revenue share of telecommunications is higher than its wage bill share (i.e., $l_j < \chi_j$), or that the sector is relatively capital-intensive compared to other sectors, the aggregate labor share tends to increase due to a positive between-sector change. In net, a strong influx of workers into healthcare, along with rapid capital accumulation and technological progress in telecommunications, could imply that the overall between-sector change in the aggregate labor share is quantitatively small, even if both shocks are quantitatively large. We now show that this pattern holds more generally across all

[11]To see this more formally, consider a percentage decrease of $\Delta x_j < 0$ in sector $j$'s revenue and wage bill. It is simple to show that the percentage change in the aggregate labor share is then given by $\Delta \ln(s^L) = (l_{j,t-1} - \chi_{j,t-1})\Delta x_j$. Note that $l_{j,t-1} - \chi_{j,t-1}$ can also be written as $(s^L_{j,t-1} - s^L_{t-1})\chi_{j,t-1}/s^L_{t-1}$. To summarize, we get that $\Delta \ln(s^L) < 0 \Leftrightarrow l_{j,t-1} > \chi_{j,t-1} \Leftrightarrow s^L_{j,t-1} > s^L_{t-1}$ or that the labor share will decrease if and only if the labor share in sector $j$ is larger than the economy-wide labor share.

sectors of the US economy since 2000.

The decomposition in equation (14) extends the decomposition in Acemoglu and Restrepo (2019). In particular, Acemoglu and Restrepo (2019) derive the following expression for changes in the economy-wide labor share:

$$\text{(15)} \qquad \Delta \ln(s^L) = \\ \sum_{j=1}^{J} l_{j,t-1}[\Delta N_j - \Delta I_j]/s^L_{j,t-1} \qquad \text{Task reallocation effect} \\ + \sum_{j=1}^{J} \frac{s^L_{j,t-1}}{s^L_{t-1}} \Delta \chi_j \qquad \text{Between-sector effect}$$

where the last term captures the contribution of between-sector changes that is obtained by differentiation only.[12] Therefore, the between-sector component in equation (15) is not rooted in a structural multi-sector model. The reason why Acemoglu and Restrepo (2019) do not focus on the between-sector changes is that they are quantitatively small, as illustrated by Figure 1. However, equation (14) shows that a quantitatively small between-sector effect can mask substantial countervailing changes.[13]

## 5. Data

We use the same publicly available data and data cleaning procedures as in Acemoglu and Restrepo (2019).[14] Data come from the Bureau of Economic Analysis (BEA) for 61 private-sector industries spanning 2000 to 2017, supplemented by data from the Bureau of Labor Statistics (BLS). The BEA's GDP by Industry accounts provide details on value added and the wage bill for each industry, classified according to the 2007 NAICS system. Additionally, we incorporate data from the BLS Multifactor Productivity Tables, which

[12] This between-sector component is similar to the between-sector component in equation (1) above. The only difference is that the between-sector component in equation (1) is an approximation of actual changes, whereas the between-sector component in equation (15) is exact but only if our model is true.

[13] Note that product markets are assumed to be perfectly competitive, which excludes the role of price markups over marginal costs. For example, if markups capture market power, they will increase the profit share and decrease the labor share within a sector. Moreover, if markups increase differently between sectors, the aggregate labor share will also change between sectors. Modeling the role of markups and quantifying their importance would be an interesting extension to this paper.

[14] The data used in Acemoglu and Restrepo (2019) can be found here. Measuring the labor share is subject to different methodological choices. Key choices include whether to use national or domestic income, how to handle taxes and depreciation, and how to divide proprietors' income into labor and capital components. See Karabarbounis (2024) for a detailed discussion.

offer industry-specific indices for labor and capital quantities.[15]

To estimate TFP growth, both the BEA and BLS publish measures that differ in important ways. The BLS measure, which this paper uses, is based on a sectoral output concept. Sectoral output equals gross output minus intra-sector transactions—that is, purchases of intermediate inputs from establishments within the same sector are subtracted. This approach eliminates double counting when aggregating productivity across establishments and prevents measured TFP growth from being affected by changes in vertical integration. For example, if a firm begins outsourcing an activity it previously performed in-house (or vice versa), this does not distort the productivity measure. The BLS constructs these measures for major sectors of the private business economy using detailed input-output data, and TFP growth is calculated as the residual growth in sectoral output not explained by the growth of combined labor and capital inputs, where inputs are aggregated using cost-share weights.

However, the BLS measure excludes households, nonprofit institutions, owner-occupied housing, and government, as reliable input measures are unavailable for these sectors. In contrast, the BEA measure of TFP growth uses a gross output approach that does not correct for business-to-business transactions within industries but is fully consistent with national accounts and covers the entire economy. Since this paper examines industry-level changes in TFP growth, the BLS measure is preferable because its sectoral output concept provides a more accurate productivity measurement at disaggregated levels.[16]

Finally, we discard two pieces of data. First, we remove the year 2008, as the financial crisis introduces substantial deviations from underlying structural trends. Second, we exclude the Real Estate sector, which is an outlier in our data. These exclusions ensure that our findings are not driven by crisis-related factors or by a single sector.

## 6. Between-sector changes in the labor share

### 6.1. Predicted between-sector changes

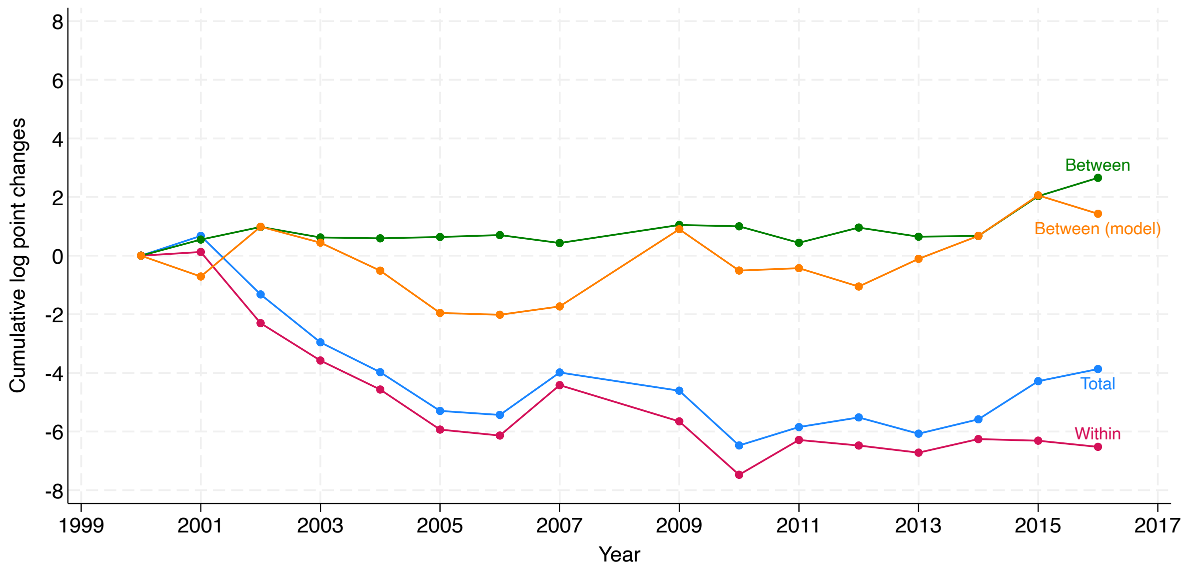
Using the data discussed in the previous section, panels A and B of Figure 2 compare the actual (green lines) and predicted (orange lines) cumulative between-sector changes in

[15] More information on the BEA GDP Industry accounts can be found here, and additional details about the BLS Multifactor Productivity Tables can be found here.

[16] Details about the BLS measure of TFP growth can be found here.

FIGURE 2. **Cumulative between-sector changes in the labor share**

A. **Predicted between-sector changes**




B. **The elasticity of substitution**

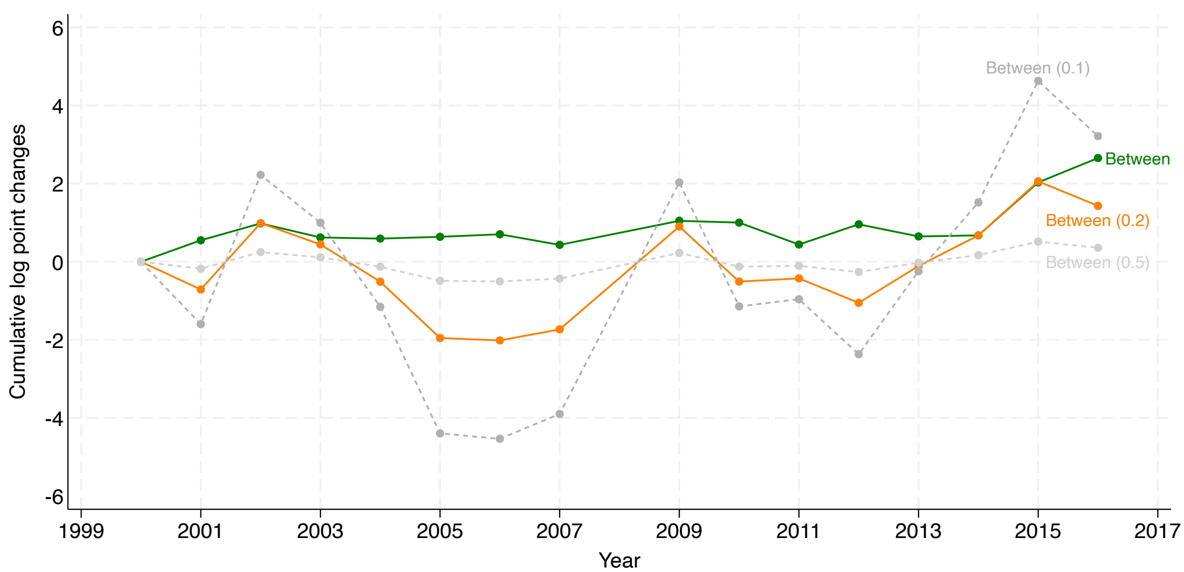
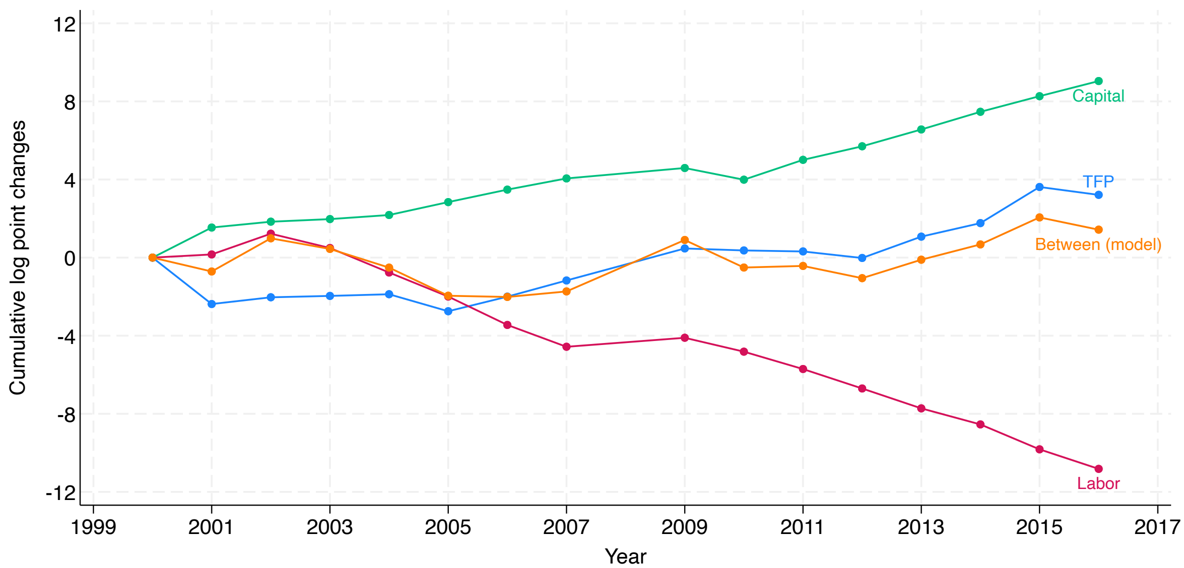


FIGURE 3. **Components of between-sector changes in the labor share**




the economy-wide labor share. The plotted actual changes (green lines) are the same as the between-sector change shown in panel B of Figure 1.[17] The predicted changes (orange lines) estimate the between-sector changes in the aggregate labor share using equation (14), assuming that $\sigma = 0.2$. Panel A shows that our model can closely track actual between-sector changes in the long-run. As for the actual changes, our model also predicts that between-sector changes are overall quantitatively less important than within-sector changes. Panel B calibrates a value for $\sigma = 0.2$ by minimizing the difference between the model's predicted and actual changes in the aggregate labor share in the long-run. A value of $\sigma = 0.1$ would predict between-sector changes that vary too much over time, whereas a value of $\sigma = 0.5$ would result in between-sector changes that vary too little.

## 6.2. Components of between-sector changes

The model's between-sector changes, shown in Figure 2, are predicted using the various between-sector terms on the right-hand side of equation (14). Therefore, we can also separately quantify the contributions of labor size, capital size, and TFP growth effects to the model's predicted between-sector changes in the economy-wide labor share.

[17]The total and within-sector changes in panel A of Figure 2 are the same as those in panel B of Figure 1.

Figure 3 again plots the overall cumulative between-sector changes predicted by our model (orange line). In addition, the figure plots the cumulative aggregate labor size, capital size, and TFP growth effects. Note that the sum of these effects adds up to the overall between-sector change in each year. Although the overall between-sector changes are quantitatively small, Figure 3 shows that the underlying sector-specific shocks in factor quantities and TFP growth rates are quantitatively large. For example, if only labor had been reallocated between sectors, the economy-wide labor share would have decreased by 11 percentage points between 2000 and 2016. Alternatively, if only capital had been allowed to accumulate differently across sectors, the aggregate labor share would have increased by 9 percentage points. Both of these simulations predict larger between-sector changes (in absolute value) in the economy-wide labor share than the within-sector changes documented in panel A of Figure 2. This shows that structural change in the US economy is important, but it also demonstrates that this has countervailing effects on the economy-wide labor share.[18]

### 6.3. Explaining between-sector changes

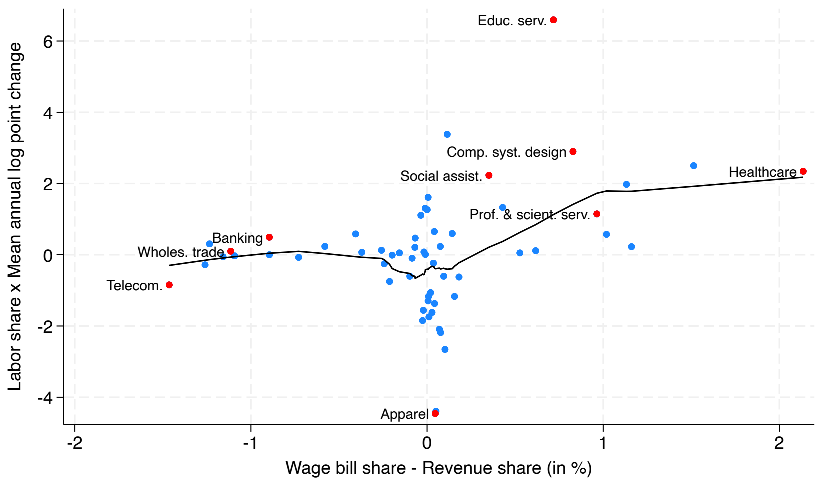
To better understand these countervailing effects, this subsection examines each sector's contribution to the labor size, capital size, and TFP growth components in equation (14). For each sector, each panel in Figure 4 plots $l_{j,t-1} - \chi_{j,t-1}$ (in percentages) on the horizontal axis. On the vertical axis, panel A plots $s^L_{j,t-1}\Delta \ln(L_j)$ (in log points) averaged across years for each sector. Similarly, the vertical axis in panel B plots the average annual $[1 - s^L_{j,t-1}]\Delta \ln(K_j)$ (in log points) for each sector, and panel C shows each sector's mean annual log point change in TFP. In each panel, the black solid lines are smoothed predictions from a locally weighted regression to summarize the correlation between the variables on the vertical and horizontal axes.

Panel A of Figure 4 shows that the largest increases in sectoral output due to employment growth occurred, among others, in educational services; computer systems design (i.e., firms that provide IT expertise such as custom software development, systems integration, and other technical support for complex IT needs); social assistance; healthcare; and professional and scientific services (i.e., businesses offering highly specialized expertise such as legal, accounting, engineering, design, computer, and con-

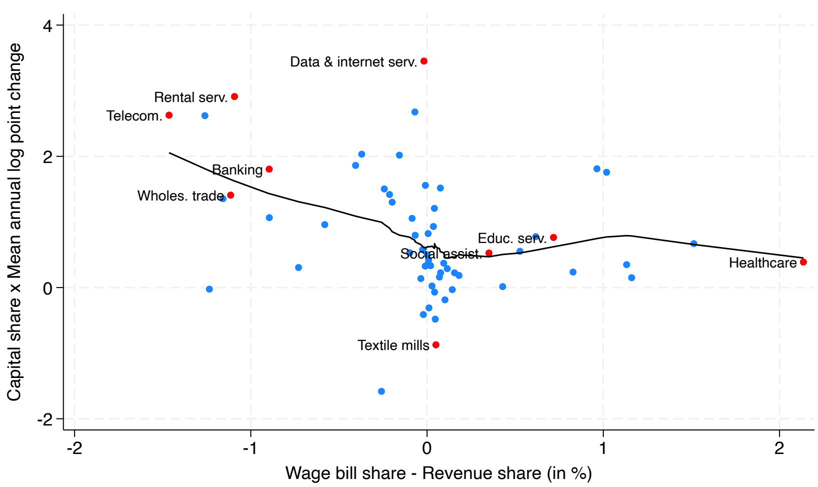
[18]Assuming a different value for $\sigma = 0.2$ would not qualitatively change this result. For example, a value of $\sigma = 0.5$ would reduce the size of all components in Figure 3 by a factor of 4, as if the y-axis were being shrunk. The reason for this is that equation (14) shows that each between-sector component depends on $(\sigma - 1)/\sigma$, which is decreasing in absolute value in $\sigma$.

FIGURE 4. **Explaining between-sector changes**

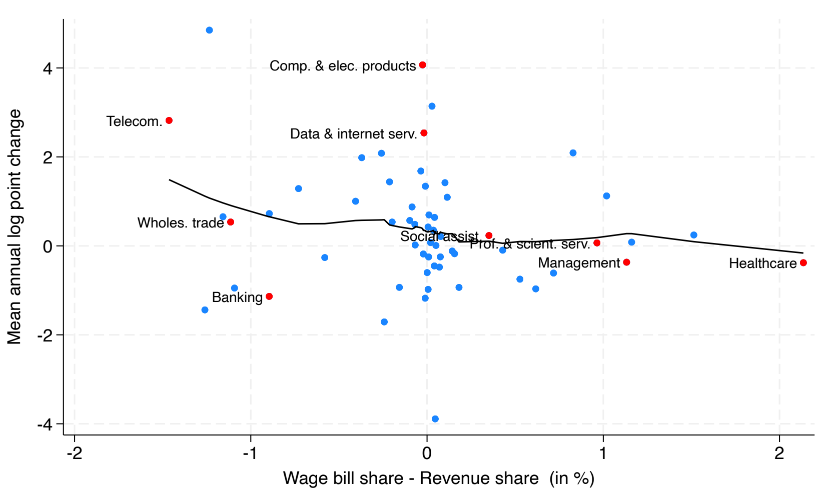
A. **Employment growth** ($\Delta \ln(L_j)$)




B. **Capital accumulation** ($\Delta \ln(K_j)$)




C. **TFP growth** ($\Delta \ln(Y_j) | K_j, L_j$)



sulting services). Because jobs in all these sectors are relatively well-paid, each sector's wage bill share exceeds its revenue share. At the same time, employment growth was less strong in banking (including banks, credit unions, mortgage lenders, and monetary authorities, but excluding pure insurance); wholesale trade; and telecommunications (covering radio/TV stations, cable, and telecommunications networks, excluding the internet). Because these sectors are relatively capital intensive, each of these sectors has a higher revenue share than wage bill share. Consequently, the reallocation of employment towards more labor-intensive sectors, such as in-person services and suppliers of IT expertise, and away from more capital-intensive sectors, such as banking, wholesale trade, and telecommunications, explains the negative labor size effects in Figure 3.[19]

Panel B of Figure 4 examines the impact of sector-specific capital accumulation on between-sector changes in the aggregate labor share. In contrast to panel A, capital accumulation was stronger in capital-intensive sectors, such as rental services (covering businesses renting or leasing tangible (e.g., vehicles, machinery) or intangible (e.g., patents, trademarks) assets); telecommunications; banking; and wholesale trade, than in labor-intensive sectors, such as education; healthcare; and social assistance, resulting in a negative correlation between the variables on the vertical and horizontal axes. The same is true for panel C of Figure 4, although the correlation between both variables is somewhat less strong. Consequently, capital accumulation and technological progress are stronger in capital-intensive sectors than in labor-intensive sectors, contributing to an increase in the aggregate labor share between-sectors, as indicated by Figure 3.[20] Finally, note that some technology-related sectors, such as data and internet services; and the manufacturing of computer and electronic products, have seen strong capital accumulation and/or TFP growth. However, because the wage bill shares and revenue shares for these sectors are almost the same, these changes have contributed very little to between-sector changes in the US labor share.

[19] Note that apparel manufacturing has seen the largest decline in employment, as has also been documented by, e.g., Autor, Dorn, and Hanson (2013). However, because the wage bill share is very close to the revenue share for this sector, its impact on the economy-wide labor share is small.

[20] Although our model differs from that in Baumol (1967), this result is intuitively similar to Baumol's cost disease. The aggregate labor share increases because capital accumulation and technological progress are concentrated in capital-intensive sectors, thereby shielding workers, who are disproportionately employed in labor-intensive sectors.

## 7. Conclusion

Commentators have argued that the current direction of AI is such that there will not be a single task in the entire economy where humans have a comparative advantage over capital. Labor becomes worthless such that its share in national income becomes zero, so the argument goes. However, this paper shows that these big, world altering scenarios are an extreme endpoint. As long as labor still plays a role, various forces can ensure that a world with zero labor share is not inevitable.

First, it is unlikely that AI will automate all labor tasks, resulting in an ever decreasing labor share within each sector. Our simple task-based framework suggests that innovation could also augment workers in their tasks, thereby increasing the labor share within firms and sectors. Fundamentally, whether the labor share will continue to decrease within sectors depends on the tasks we want AI to perform, the new tasks AI will create for workers, and the comparative advantage between AI and humans in performing these tasks.

Second, there are various forces in the economy that could prevent an ever-declining labor share. If the impact of AI also manifests through changes in market structure, market forces will also play a role. To demonstrate this, this paper uses a simple and empirically tractable framework to illustrate the importance of equilibrium forces that arise from changes in relative product demands due to sector-specific shocks. Using this framework, this paper shows that the stability of overall between-sector changes in the US labor share has been merely a coincidence of offsetting equilibrium changes in consumer demand resulting from sector-specific changes in factor supplies and technological progress. However, AI could unleash market forces that increase or decrease between-sector changes in the economy-wide labor share.

These and other market forces and institutions, such as diminishing returns in capital markets (e.g., a rapid depreciation of AI chips), shortages in labor markets (e.g., due to aging populations), changes in product and labor market power, or unions, can help explain the impact of past episodes of technological progress on the labor share, why changes in the labor share differ between countries, and why capital income from AI must dwarf labor income in the future. This paper has provided an intuitively simple and empirically tractable framework that one can build on to answer these questions based on richer sectoral data.

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# Appendices (for online publication)

# Appendix A. Changes in the labor share within and between sectors

## A.1. Changes within and between sectors

We assume that time is discrete with $\Delta X \equiv X_t - X_{t-1}$ the change in $X$ between time periods $t-1$ and $t$. Following Acemoglu and Restrepo (2019), the change in the economy-wide labor share between periods $t-1$ and $t$ can be decomposed using the following approximation:

$$(A.1) \qquad \Delta \ln(s^L) \approx$$

$$\ln\left(\sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t}\right) - \ln\left(\sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t-1}\right) \qquad \text{Within-sectors}$$

$$+\ln\left(\sum_{j=1}^{J} s^L_{j,t-1} \chi_{j,t}\right) - \ln\left(\sum_{j=1}^{J} s^L_{j,t-1} \chi_{j,t-1}\right) \qquad \text{Between-sectors}$$

To derive equation (A.1), start by writing the economy-wide wage bill at time $t$ as:

$$(A.2) \qquad W_t L_t = \sum_{j=1}^{J} W_{j,t} L_{j,t} = \sum_{j=1}^{J} P_{j,t} Y_{j,t} s^L_{j,t} = \sum_{j=1}^{J} Y_t \chi_{j,t} s^L_{j,t}$$

with $\chi_{j,t} \equiv P_{j,t} Y_{j,t} / Y_t$. Differentiating over time gives:

$$(A.3) \qquad \Delta(WL) = \sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t-1} \Delta Y + \sum_{j=1}^{J} Y_{t-1} s^L_{j,t-1} \Delta \chi_j + \sum_{j=1}^{J} Y_{t-1} \chi_{j,t-1} \Delta s^L_j$$

Dividing by $W_{t-1} L_{t-1}$ gives:

$$(A.4) \qquad \Delta \ln(WL) =$$

$$\sum_{j=1}^{J} l_{j,t-1} \Delta \ln(s^L_j) \qquad \text{Within-sector effect}$$

$$+ \sum_{j=1}^{J} \frac{s^L_{j,t-1}}{s^L_{t-1}} \Delta \chi_j \qquad \text{Between-sector effect}$$

$$+\Delta \ln(Y) \qquad \text{Aggregate income effect}$$

with $s^L_{t-1} \equiv W_{t-1} L_{t-1} / Y_{t-1}$ the economy-wide labor share and $l_{j,t-1} \equiv W_{j,t-1} L_{j,t-1} / W_{t-1} L_{t-1}$.

The within-sector effect in equation (A.4) can be approximated by:

$$
\begin{aligned}
\sum_{j=1}^{J} l_{j,t-1} \Delta \ln(s_j^L) &= \sum_{j=1}^{J} l_{j,t-1} \left[\ln(s_{j,t}^L) - \ln(s_{j,t-1}^L)\right] \\
&= \sum_{j=1}^{J} \frac{W_{j,t-1} L_{j,t-1}}{W_{t-1} L_{t-1}} \left[\ln(s_{j,t}^L) - \ln(s_{j,t-1}^L)\right] \\
&= \sum_{j=1}^{J} \left[ \frac{\frac{P_{j,t-1} Y_{j,t-1}}{Y_{t-1}} \frac{W_{j,t-1} L_{j,t-1}}{P_{j,t-1} Y_{j,t-1}}}{\sum_{j=1}^{J} \left[ \frac{P_{j,t-1} Y_{j,t-1}}{Y_{t-1}} \frac{W_{j,t-1} L_{j,t-1}}{P_{j,t-1} Y_{j,t-1}} \right]} \right] \left[\ln(s_{j,t}^L) - \ln(s_{j,t-1}^L)\right] \\
&= \sum_{j=1}^{J} \frac{\chi_{j,t-1} s_{j,t-1}^L}{\sum_{j=1}^{J} \chi_{j,t-1} s_{j,t-1}^L} \left[\ln(s_{j,t}^L) - \ln(s_{j,t-1}^L)\right] \\
&= \sum_{j=1}^{J} \frac{\partial \ln(\sum_{j=1}^{J} \chi_{j,t-1} s_{j,t-1}^L)}{\partial \ln(s_{j,t-1}^L)} \left[\ln(s_{j,t}^L) - \ln(s_{j,t-1}^L)\right] \\
&\approx \ln(\sum_{j=1}^{J} \chi_{j,t-1} s_{j,t}^L) - \ln(\sum_{j=1}^{J} \chi_{j,t-1} s_{j,t-1}^L) \qquad \text{(A.5)}
\end{aligned}
$$

and the between-sector effect in equation (A.4) can be approximated by:

$$
\begin{aligned}
\sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \Delta \chi_j &= \sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \left[\chi_{j,t} - \chi_{j,t-1}\right] \\
&= \frac{1}{\sum_{j=1}^{J} \chi_{j,t-1} s_{j,t-1}^L} \left[ \sum_{j=1}^{J} s_{j,t-1}^L \chi_{j,t} - \sum_{j=1}^{J} s_{j,t-1}^L \chi_{j,t-1} \right] \\
&\approx \ln(\sum_{j=1}^{J} s_{j,t-1}^L \chi_{j,t}) - \ln(\sum_{j=1}^{J} s_{j,t-1}^L \chi_{j,t-1}) \qquad \text{(A.6)}
\end{aligned}
$$

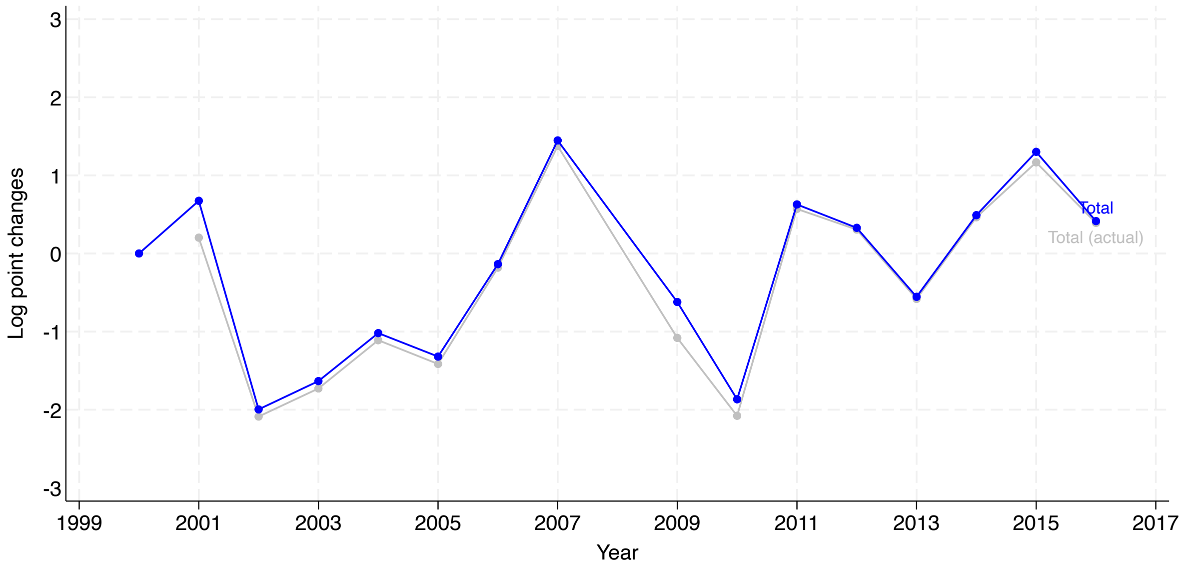
Combining equations (A.4), (A.5), and (A.6) gives equation (A.1).

### A.2. Approximate versus exact changes in the labor share

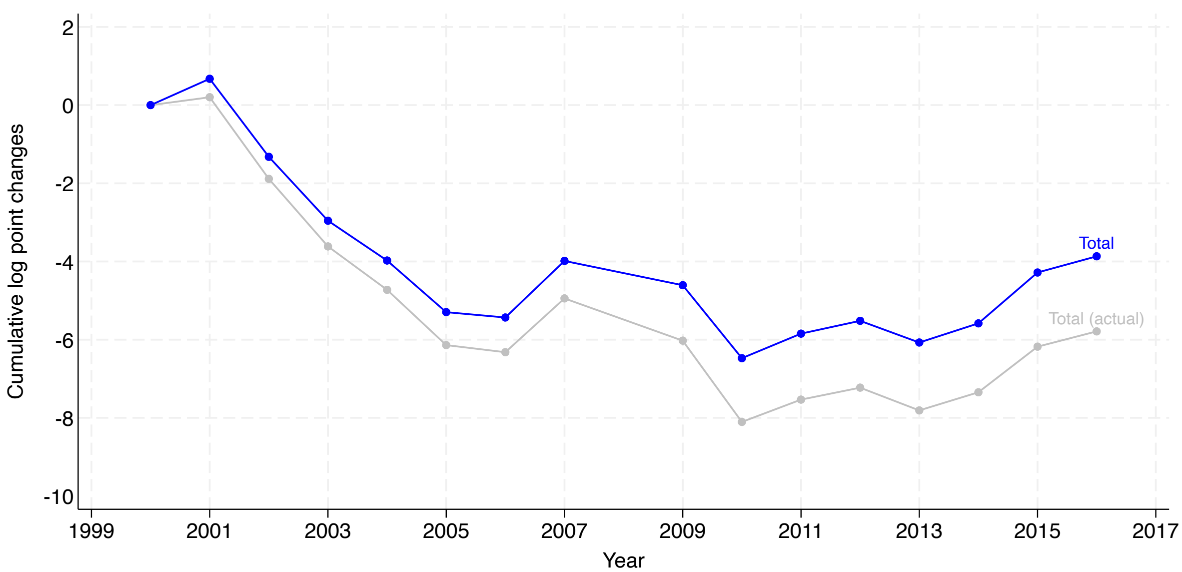
The decomposition in equation (A.1) is not exact because the last steps in deriving equations (A.4) and (A.5) use first-degree Taylor polynomials. Figure A.1 shows the differences between the approximated (blue lines) and actual (gray lines) annual (panel A) and cumulative (panel B) changes in the economy-wide labor share.

FIGURE A.1. **Approximate versus exact changes in the labor share**

A. **Annual changes**




B. **Cumulative annual changes**




**Notes**: The grey lines plot the actual changes in the economy-wide labor share. The blue lines plot the approximate total changes in the economy-wide labor share given by the left-hand side of equation (1). See Section 5 for a discussion of data sources.

# Appendix B. Model

## B.1. Equilibrium

Define $R_j$ as the price of capital and $W_j$ as the price of labor. That is, $R_j$ is the price of one unit of $k_j(z)$ and $W_j$ is the price of one unit of $l_j(z)$. For given values of $R_j$ and $W_j$, the unit-cost of task $z$, $p_j(z)$, is given by:

(B.1)
$$p_j(z) = \begin{cases} R_j / \left[A^K \gamma_j^K(z)\right] & \text{if} \quad z \in [N_j - 1, I_j] \\ W_j / \left[A^L \gamma_j^L(z)\right] & \text{if} \quad z \in (I_j, N_j] \end{cases}$$

Given that equation (5) is a Cobb-Douglas production function using a continuum of tasks on a unit-interval, cost shares must be constant and equal across all tasks in equilibrium. In particular, we must have that $\forall z: \; p_j(z) y_j(z) = P_j Y_j$. Using that $y_j(z) = P_j Y_j / p_j(z)$ together with equations (6) and (B.1), we get that:

(B.2)
$$k_j(z) = \begin{cases} P_j Y_j / R_j & \text{if} \quad z \in [N_j - 1, I_j] \\ 0 & \text{if} \quad z \in (I_j, N_j] \end{cases} \qquad l_j(z) = \begin{cases} 0 & \text{if} \quad z \in [N_j - 1, I_j] \\ P_j Y_j / W_j & \text{if} \quad z \in (I_j, N_j] \end{cases}$$

which gives the demands for capital and labor for each task $z$, respectively.

Using equations (7) and (B.2) then solves for $W_j L_j$ and $R_j K_j$:

(B.3)
$$W_j L_j = P_j Y_j [N_j - I_j] = P_j Y_j s^L(I_j, N_j)$$

and

(B.4)
$$R_j K_j = P_j Y_j [I_j - N_j + 1] = P_j Y_j [1 - s^L(I_j, N_j)]$$

where $s^L(I_j, N_j) \equiv W_j L_j / [P_j Y_j] = N_j - I_j$ is the labor share in sector $j$.

In equilibrium, $P_j$ must be equal to the marginal cost of $Y_j$. Given the Cobb-Douglas production function in equation (5), the corresponding expression for the marginal cost of producing $Y_j$ is given by:

(B.5)
$$P_j = \exp\left[\int_{N_j - 1}^{N_j} \ln(p_j(z)) dz\right]$$

Substitute expressions for $W_j$ and $R_j$ from equations (B.3) and (B.4) into equation (B.1). Then substitute equation (B.1) into equation (B.5). Taking logarithms, we get that:

$$\begin{aligned}\text{(B.6)} \qquad \ln(Y_j) = & \int_{N_j-1}^{I_j} \ln(\gamma_j^K(z))dz + \int_{I_j}^{N_j} \ln(\gamma_j^L(z))dz \\ & + [1 - s^L(I_j, N_j)] \ln(\frac{A^K K_j}{1 - s^L(I_j, N_j)}) + s^L(I_j, N_j) \ln(\frac{A^L L_j}{s^L(I_j, N_j)})\end{aligned}$$

We can now write output, $Y_j$, as the following Cobb-Douglas aggregate:

$$\text{(B.7)} \qquad Y_j = \Pi(I_j, N_j) \left[\frac{A^K K_j}{1 - s^L(I_j, N_j)}\right]^{1-s^L(I_j,N_j)} \left[\frac{A^L L_j}{s^L(I_j, N_j)}\right]^{s^L(I_j,N_j)}$$

with $\Pi(I_j, N_j)$ defined as:

$$\Pi(I_j, N_j) \equiv \exp\left[\int_{N_j-1}^{I_j} \ln(\gamma_j^K(z))dz + \int_{I_j}^{N_j} \ln(\gamma_j^L(z))dz\right]$$

### B.2. Factor size effects

The expression for the factor size effects in equation (12) generalizes to any CRS production function. To see this, assume that a sector's output, $Y$, uses $F$ input factors, $f = 1, ..., F$. Conditional factor demands in the sector are then given by:

$$\text{(B.8)} \qquad X = C_w(W)Y$$

with $X$ an $F \times 1$ vector of conditional factor demands, and with $C_w(W)$ an $F \times 1$ vector of unit factor demands (i.e. a column vector of $F$ partial derivatives of the marginal cost function with respect to that factor's price $w_f$).

Totally differentiating gives:

$$\text{(B.9)} \qquad dX = C_w(W)dY + YC_{ww}(W)dW$$

Multiplying by $W$ and using that the cost function is linear homogeneous such that $W'C_{ww} = 0$, we get:

$$\text{(B.10)} \qquad W'dX = W'C_w(W)dY = W'X(dY/Y)$$

Rearranging terms gives:

(B.11)
$$d\ln(Y) = W'(Xd\ln(X))/W'X$$

This is equivalent to the equation:

(B.12)
$$d\ln(Y) = \sum_{f=1}^{F} s^f d\ln(x_f)$$

with $s^f$ the cost share of factor $f$ and $x_f$ the quantity used of factor $f$.

## B.3. The impact of technological progress on TFP

Equation (12) was given by:

(B.13)
$$d\ln(Y_j) = \left\{ s^L(I_j, N_j)d\ln(L_j) + [1 - s^L(I_j, N_j)]d\ln(K_j) \right\} + d\ln(Y_j)_{|K_j, L_j}$$

where the first term on the right-hand side of equation (B.13), $d\ln(Y_j)|K_j, L_j$, can be obtained from differentiating equation (B.6):

(B.14)
$$\frac{d\ln(Y_j)}{dI_j}|K_j, L_j = \ln\left(\frac{W_j}{A^L\gamma^L(I_j)} / \frac{R_j}{A^K\gamma^K(I_j)}\right)$$

(B.15)
$$\frac{d\ln(Y_j)}{dN_j}|K_j, L_j = \ln\left(\frac{R_j}{A^K\gamma^K(N_j - 1)} / \frac{W_j}{A^L\gamma^L(N_j)}\right)$$

(B.16)
$$\frac{d\ln(Y_j)}{d\ln(A^K)}|K_j, L_j = 1 - s^L(I_j, N_j)$$

(B.17)
$$\frac{d\ln(Y_j)}{d\ln(A^L)}|K_j, L_j = s^L(I_j, N_j)$$

with $d\ln(Y_j)|K_j, L_j$ is the sum of all these effects combined.

## Appendix C. Graphical analyses of changes in labor incomes

Without loss of generality, this appendix assumes that $\sigma < 1$.

### C.1. Changes in (effective) factor supplies

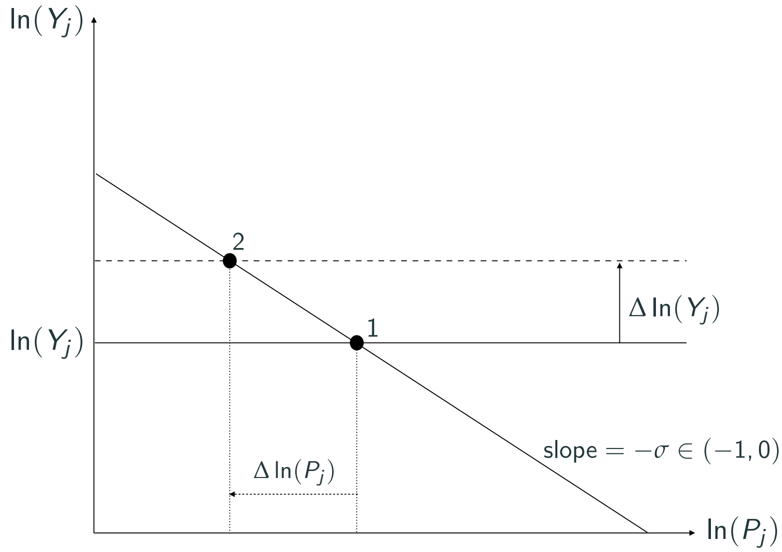
Start from equation (10). First, consider an increase in $\ln(K_j)$ or $\ln(A^K)$ for given $\ln(A^L)$ and $\ln(L_j)$. Panel (a) of Figure C.1 considers its impact on (log) sectoral revenue: sectoral output, $\ln(Y_j)$, increases, shifting the horizontal line up and reducing $\ln(P_j)$ as we move from point 1 to point 2. Because it is assumed that $\sigma < 1$, sectoral revenue, $P_j Y_j$, must fall. Panel (b) of Figure C.1 shows what happens to labor income, $W_j L_j$. It plots the log of sectoral employment, $\ln(L_j)$, on the vertical axis, and the log of the consumer wage of workers in sector $j$, $\ln(W_j)$, on the horizontal axis. The downward sloping line is obtained from substituting equation (9) into (8), taking logs and rearranging terms. Because $W_j L_j = s^L(I_j, N_j) P_j Y_j$, a decrease in $P_j Y_j$ implies that $W_j L_j$ must decrease or, for given $L_j$, that $W_j$ must decrease. Starting at point 3, this is captured by the inward shift of the downward sloping line, which moves equilibrium from point 3 to point 4. In point 4, the consumer wage of workers in sector $j$, $W_j$, has decreased. However, the decrease in $W_j$ will be less than the decrease in $P_j$ because the producer wage, $W_j/P_j$, must increase due to the q-complementarity between capital and labor in production.

Next, consider an increase in $\ln(A^L)$ for given $\ln(A^K)$, $\ln(K_j)$, and $\ln(L_j)$. It's impact on sectoral revenue, $P_j Y_j$, is again captured by moving from point 1 to point 2 in panel (a) of Figure C.1. Because it is assumed that $\sigma < 1$, sectoral revenue must decrease. Turning to panel (b) of Figure C.1, a decrease in sectoral revenue implies that labor income, $W_j L_j$, must also decrease due to a decrease in the consumer wage of workers in sector $j$, $W_j$. If production is Cobb-Douglas as assumed in equation (9), the producer wage, $W_j/P_j$, must increase, and labor income moves from point 3 to point 4.[21]

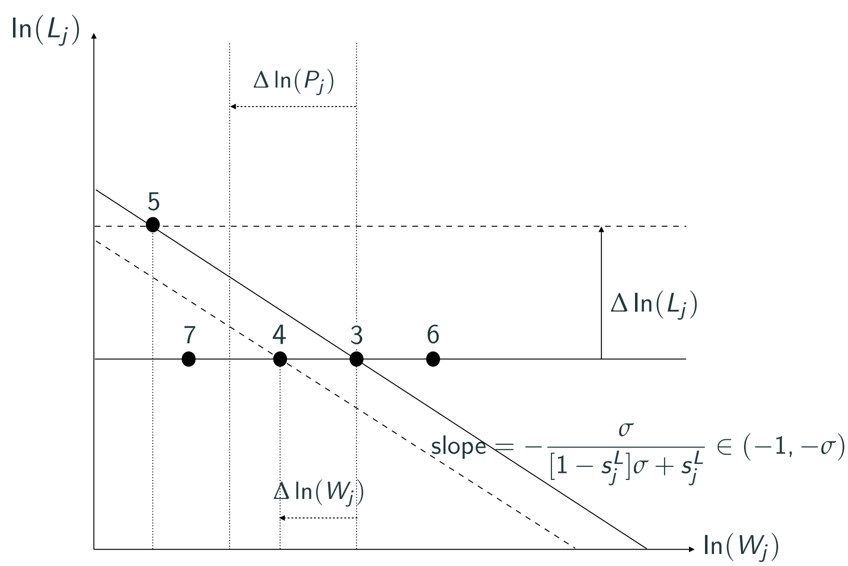
Finally, consider an increase in $\ln(L_j)$ for given $\ln(A^K)$, $\ln(K_j)$, and $\ln(A^L)$. Panel (a) of Figure C.1 again captures the impact on sectoral revenue, $P_j Y_j$, which will decrease as we move from point 1 to point 2. Panel (b) of Figure C.1 shows what happens to

[21] In general, it is ambiguous whether we move from point 3 to point 4 such that the producer wage increases, or from point 3 to point 7 such that the producer wage decreases. In any production function with two factors and constant returns to scale, the producer wage will increase if the capital share is less than the elasticity of substitution between capital and labor in production. See Acemoglu and Restrepo (2018) for details. If production is Cobb-Douglas such that the elasticity of substitution between capital and labor is unity, this will always be true, so the producer wage must always increase.

FIGURE C.1. **Comparative statics for changes in (effective) factor supplies and technological progress**




A. Sectoral revenue




B. Labor income

labor income. Because $\ln(L_j)$ increases, the horizontal line shifts upward, and we move from point 3 to point 5. In point 5, the consumer wage of workers in sector $j$, $W_j$, has decreased. Moreover, because $\sigma < 1$, this decrease in $W_j$ will also decrease $W_j L_j$. Finally, $W_j$ will decrease by more than $P_j$ because the producer wage, $W_j/P_j$, must decrease given the increased supply of labor in sector $j$.

### C.2. Automation and new task creation

Consider an increase in $I_j$ or $N_j$. As before, the impact on sectoral revenue is given by the shift from point 1 to point 2 in panel (a) of Figure C.1, which captures that automation and new tasks will reduce sectoral revenue, $P_j Y_j$, if $\sigma < 1$. However, the impact on the sector's wage bill in panel (b) is different because the labor share also changes.

If $N_j$ increases for given $I_j$, the labor share increases. Because $W_j L_j = s^L(I_j, N_j) P_j Y_j$ and $L_j$ is assumed constant, the downward sloping line will shift so that $W_j$ will decrease less and could even increase, as illustrated by the shift from point 3 to point 6 in panel (b) of Figure C.1. The producer wage, $W_j/P_j$, will increase due to a sector-specific productivity effect, captured by the shift from point 3 to point 4, as well as a direct reinstatement effect driven by an increase in the sector's labor share, captured by a shift from point 4 to point 6.

Alternatively, if $I_j$ increases for given $N_j$, the decrease in labor share implies that the downward sloping line in panel (b) of Figure C.1 shifts inward more and we move from point 3 to point 7, where $W_j$ has decreased more. Also, $W_j/P_j$ will increase less and could even fall, as is the case in the figure. The fall in the producer wage results from a competing productivity effect which tends to increase the producer wage, captured by a shift from point 3 to point 4, that is dominated by a direct displacement effect due to a decrease in the sector's labor share, captured the shift from point 4 to point 7.

Finally, the changes in labor income depicted in panel (b) of Figure C.1 can be decomposed into changes between and within sectors. The shifts from point 3 to point 4 or 5 (or a combination) capture changes in relative output prices and consumption following sector-specific changes in factor supplies and technological progress, keeping the labor share within each sector constant over time. In addition, the shifts from point 4 to point 6 or 7 (or a combination) capture changes in a sector's labor share if technological progress automates or creates labor tasks.

### C.3. Changes in aggregate income

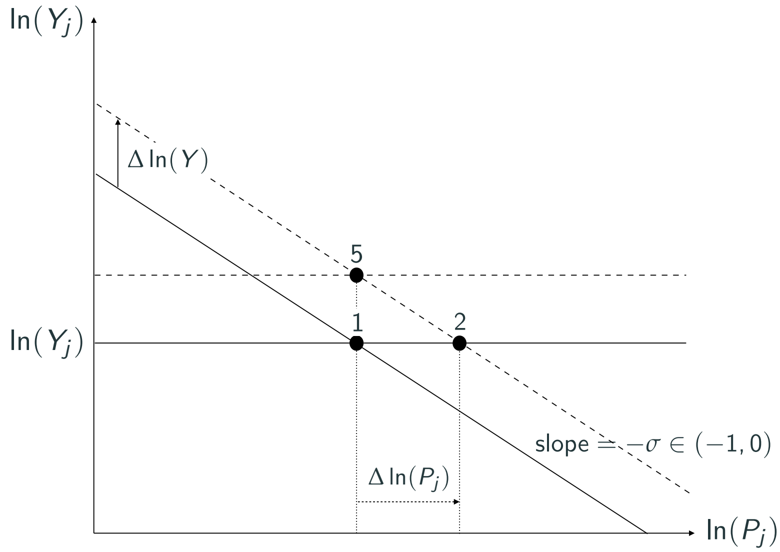
Next, consider an increase in aggregate real income, $\ln(Y)$, all else being equal. Panel (a) of Figure C.2 considers its impact on sectoral revenue: the sectoral output price, $\ln(P_j)$, increases as the product demand curve shifts from point 1 to point 2. Consequently, sectoral revenue, $P_j Y_j$, must increase if $Y_j$ remains constant. Panel (b) of Figure C.2 shows what happens to labor income, $W_j L_j$. Because $W_j L_j = s^L(I_j, N_j)P_j Y_j$, an increase in $P_j$ implies that $W_j L_j$ must increase or, for given $L_j$, that $W_j$ must increase. Starting at point 3, this is captured by the outward shift of the downward sloping line, which moves equilibrium from point 3 to point 4. In point 4, the consumer wage of workers in each sector $j$, $W_j$, has increased. This increase in $W_j$ will be equal to the increase in $P_j$ because the producer wage, $W_j/P_j$, will not change for constant $Y_j$.

If this aggregate income effect results from technological progress and increased factor supplies in sectors other than $j$, the increase in the consumer wage, $W_j$, captures a spillover effect due to a decrease in the prices of goods other than $j$. Equation (13) shows that this spillover effect is larger if $\sigma$ is smaller or if product demand is more inelastic. However, given that $d\ln(Y) = \sum_{j=1}^{J} \chi_{j,t-1} d\ln(P_j Y_j)$, this spillover effect decreases over time if the revenue share of sectors other than $j$ decreases over time.

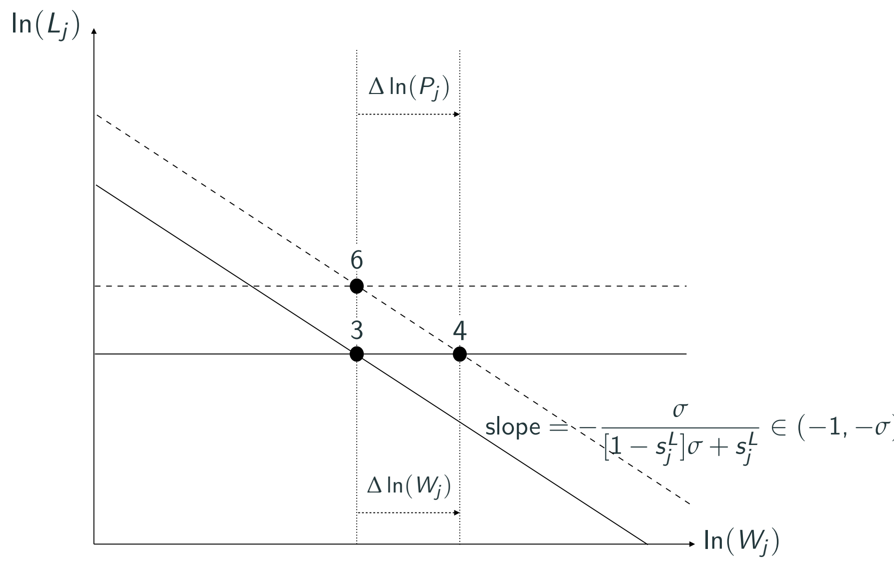
Finally, two special cases are worth noting. First, consider the case where technological progress is identical in all sectors. If so, we have that $d\ln(Y_j) = d\ln(Y) > 0$ and $d\ln(P_j) = 0$, captured by a shift from point 1 to point 5 in panel (a) of Figure C.2 in each sector. For a given $L_j$, we must then also have $d\ln(W_j) = d\ln(Y_j) + d\ln(s_j^L) = d\ln(Y) + d\ln(s^L)$. That is, there exists only a common within-sector and an aggregate income effect. There is no between-sector effect, and the analysis effectively simplifies to a one-sector model. A shift from point 3 to point 4 in panel (b) of Figure C.2 would illustrate this case, assuming that $d\ln(Y) + d\ln(s^L) > 0$. In this case, also note that $W_j/P_j$ increases given that $d\ln(W_j) > 0$ and $d\ln(P_j) = 0$.

Second, consider the case in which $L_j$ and $K_j$ increase in the same proportion in each sector. We then have that $d\ln(L_j) = d\ln(K_j) = d\ln(Y_j) = d\ln(Y) > 0$ and $d\ln(P_j) = 0$, again captured by a change from point 1 to point 5 in panel (a) of Figure C.2 in each sector. In panel (b) of Figure C.2, the horizontal line shifts upwards due to an increase in $L_j$ and the downward sloping line shifts outward due to an increase in $Y$. Because $d\ln(W_j) = d\ln(Y_j) - d\ln(L_j) = 0$, we move from point 3 to point 6. There is only an aggregate income effect, illustrating the assumption of a constant returns to scale economy.

FIGURE C.2. **Comparative statics for changes in aggregate income**




A. Sectoral revenue




B. Labor income

## Appendix D. Decomposing changes in the labor share

Equation (A.4) was given by:

(D.1) $\Delta \ln(WL) =$

$$\sum_{j=1}^{J} l_{j,t-1} \Delta \ln(s_j^L) \qquad \text{Within-sector effect}$$

$$+ \sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \Delta \chi_j \qquad \text{Between-sector effect}$$

$$+ \Delta \ln(Y) \qquad \text{Aggregate income effect}$$

Moving $\Delta \ln(Y)$ to the left-hand side gives:

(D.2) $\Delta \ln(s^L) =$

$$\sum_{j=1}^{J} l_{j,t-1} \Delta \ln(s_j^L) \qquad \text{Within-sector effect}$$

$$+ \sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \Delta \chi_j \qquad \text{Between-sector effect}$$

The between-sector effect in equation (D.2) can be written as:

$$\begin{aligned}
\sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \Delta \chi_j &= \sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \Delta \left( \frac{P_j Y_j}{Y} \right) \\
&= \sum_{j=1}^{J} \frac{s_{j,t-1}^L}{s_{t-1}^L} \frac{P_{j,t-1} Y_{j,t-1}}{Y_{t-1}} \Delta \ln \left( \frac{P_j Y_j}{Y} \right) \\
&= \sum_{j=1}^{J} \frac{W_{j,t-1} L_{j,t-1}}{P_{j,t-1} Y_{j,t-1}} \frac{Y_{t-1}}{W_{t-1} L_{t-1}} \frac{P_{j,t-1} Y_{j,t-1}}{Y_{t-1}} \Delta \ln(P_j Y_j / Y)
\end{aligned}$$

(D.3)
$$= \sum_{j=1}^{J} l_{j,t-1} \Delta \ln(P_j Y_j / Y)$$

Next, re-write the last term in equation (D.3) as:

(D.4)
$$\Delta \ln(P_j Y_j / Y) = \Delta \ln(P_j Y_j) - \left[ \frac{1}{\sigma} + \frac{\sigma - 1}{\sigma} \right] \Delta \ln(Y)$$

and using the expression for $\Delta \ln(P_j Y_j)$ in equation (11) gives:

$$\text{(D.5)} \qquad \Delta \ln(P_j Y_j / Y) = \frac{\sigma - 1}{\sigma} \left[ \Delta \ln(Y_j) - \Delta \ln(Y) \right]$$

Using equation (B.13), we can write $\Delta \ln(Y)$ as:

$$\begin{aligned} \Delta \ln(Y) &= \sum_{j=1}^{J} \chi_{j,t-1} \Delta \ln(Y_j) \\ \text{(D.6)} \qquad &= \sum_{j=1}^{J} \chi_{j,t-1} \left[ s^L_{j,t-1} \Delta \ln(L_j) + [1 - s^L_{j,t-1}] \Delta \ln(K_j) + \Delta \ln(Y_j) | K_j, L_j \right] \end{aligned}$$

Using equations (B.13) and (D.6), we can then re-write equation (D.5) as:

$$\text{(D.7)} \quad \Delta \ln(P_j Y_j / Y) = \frac{\sigma - 1}{\sigma} \times \begin{cases} s^L_{j,t-1} \Delta \ln(L_j) - \sum_{j=1}^{J} \chi_{j,t-1} s^L_{j,t-1} \Delta \ln(L_j) \\ +[1 - s^L_{j,t-1}] \Delta \ln(K_j) - \sum_{j=1}^{J} \chi_{j,t-1} [1 - s^L_{j,t-1}] \Delta \ln(K_j) \\ +\Delta \ln(Y_j) | K_j, L_j - \sum_{j=1}^{J} \chi_{j,t-1} \Delta \ln(Y_j) | K_j, L_j \end{cases}$$

Substituting equation (D.7) into (D.3), and (D.3) into (D.2) gives:

$$\begin{aligned} \text{(D.8)} \quad \Delta \ln(s^L) = &\sum_{j=1}^{J} l_{j,t-1} [\Delta N_j - \Delta I_j] / s^L_{j,t-1} && \text{Task reallocation effect} \\ &+ \frac{\sigma - 1}{\sigma} \sum_{j=1}^{J} [l_{j,t-1} - \chi_{j,t-1}] \times \begin{cases} s^L_{j,t-1} \Delta \ln(L_j) & \text{Labor size effect} \\ +[1 - s^L_{j,t-1}] \Delta \ln(K_j) & \text{Capital size effect} \\ +\Delta \ln(Y_j) | K_j, L_j & \text{TFP growth} \end{cases} \end{aligned}$$

Alternatively, using that $\chi_j s^L_j = s^L l_j$ and that $\chi_j [1 - s^L_j] = [1 - s^L] k_j$ with $k_j \equiv R_j K_j / RK$, we can write equation (D.7) as:

$$\text{(D.9)} \qquad \Delta \ln(P_j Y_j / Y) = \frac{\sigma - 1}{\sigma} \times \begin{cases} s^L_{j,t-1} \Delta \ln(L_j) - s^L_{t-1} \Delta \ln(L) \\ +[1 - s^L_{j,t-1}] \Delta \ln(K_j) - [1 - s^L_{t-1}] \Delta \ln(K) \\ +\Delta \ln(Y_j) | K_j, L_j - \Delta \ln(Y) | K, L \end{cases}$$

with $\Delta\ln(L) \equiv \sum_{j=1}^{J} l_j \Delta\ln(L_j)$ and $\Delta\ln(K) \equiv \sum_{j=1}^{J} k_j \Delta\ln(K_j)$, and with $\Delta\ln(Y)|K, L \equiv \sum_{j=1}^{J} \chi_j \Delta\ln(Y_j|K_j, L_j)$.

Substituting equation (D.10) into (D.3), and (D.3) into (D.2) gives an alternative decomposition of changes in the aggregate labor share:

(D.10) $\Delta\ln(s^L) =$

$$\sum_{j=1}^{J} l_{j,t-1}[\Delta N_j - \Delta I_j]/s^L_{j,t-1} \qquad \text{Task reallocation effect}$$

$$+\frac{\sigma-1}{\sigma}\sum_{j=1}^{J} l_{j,t-1} \times \begin{cases} s^L_{j,t-1}\Delta\ln(L_j) - s^L_{t-1}\Delta\ln(L) & \text{Labor size effect} \\ +[1-s^L_{j,t-1}]\Delta\ln(K_j) - [1-s^L_{t-1}]\Delta\ln(K) & \text{Capital size effect} \\ +\Delta\ln(Y_j)|K_j, L_j - \Delta\ln(Y)|K, L & \text{TFP growth} \end{cases}$$