Skill Biased Technical Change

Polarization of the Labor Market and Wage Inequality

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1 Introduction

Shifts in the aggregate production function have long been studied by economists. Solow (1957) first classified these shifts as technical changes that can encompass slowdowns, speedups or improvements in the education of the labor force. Solow showed that these technical changes were factor-neutral from 1909-1949. Shifts in the production function are neutral if they leave the marginal rate of transformation unchanged and simply increase or decrease the output attainable from a set of given inputs. These factor-neutral technical changes have since been widely studied and have led to the consensus that factor-neutral technology improvements are the primary source of growth in income per capita.

More recent empirical work has used a similar idea to capture and estimate the growth of relative wages of more educated workers. A simple CES model is typically used as a theoretical starting point for estimating movements of relative wages induced by skill biased technical changes that are assumed to be factor augmenting. This model has been widely used to explain trends in the labor market over the past four decades. However more recent changes, commencing in the early 1990’s are no longer consistent with such a simple model. Three noteworthy trends, which are the focus of this paper, are the increasing wage inequality between and within education groups, wage polarization and job polarization. Since these appear to be secular trends that began around the early
1990’s many authors have claimed that the diffusion of information technologies and computers is the underlying driver of this skill biased technical change. This paper explores the skill biased technical change hypothesis and resulting implications, shows how the simple model falls short in explaining wage and job polarization and suggests future work that could be done to better understand the changes we have seen in the labor market over the past two decades.

The rest of this paper is as follows. Section 2 gives a simple CES model and four implications. Section 3 analyzes recent labor market trends and compares them to the implications from the CES model. Section 4 briefly introduces two models that attempt to better capture the effects that computers and information technologies have had on the labor market. Section 5 concludes and discusses future research on the topic.

2 Skill Biased Technical Change: A Simple Model

The work of Tinbergen (1974) and Welch (1973) on the substitution between different types of workers led to a simple, tractable framework in which to study the effects of skill biased technical change. A simple CES model with two inputs, high-skilled workers ($N_H$) and low-skilled workers ($N_L$), defines aggregate output as:

$$Q = [\alpha(A_H N_H)^\rho + (1 - \alpha)(A_L N_L)^\rho]^{1/\rho} \quad (1)$$

where $\alpha$ is the share of work activities allocated to skilled labor, $A_H$ and $A_L$ are high-skilled and low-skilled labor augmenting technologies respectively. In this model skill neutral technical improvements raise $A_H$ and $A_L$ by the same proportion whereas skill biased technical change increases $A_H/A_L$ or $\alpha$. The aggregate elasticity of substitution between high and low skilled workers is $\sigma = 1/(1 - \rho)$. If $\sigma > 1$ then high and low
skilled workers are gross substitutes, when $\sigma < 1$ gross complements and when $\sigma = 1$ the production function is Cobb-Douglas.

Assuming competitive labor markets workers earn their marginal products which implies:

$$w_L = \frac{\partial Q}{\partial N_L} = (1 - \alpha)A_L^\rho \left[ \alpha A_H^\rho \left( \frac{N_H}{N_L} \right)^\rho + (1 - \alpha)A_L^\rho \right]^{\frac{1-\rho}{\rho}} \quad (2)$$

$$w_H = \frac{\partial Q}{\partial N_H} = \alpha A_H^\rho \left[ \alpha A_H^\rho + (1 - \alpha)A_L^\rho \left( \frac{N_L}{N_H} \right)^\rho \right]^{\frac{1-\rho}{\rho}} \quad (3)$$

$$\omega = \frac{w_H}{w_L} = \frac{\alpha}{1 - \alpha} \left( \frac{A_H}{A_L} \right)^\rho \left( \frac{N_L}{N_H} \right)^{1-\rho} \quad (4)$$

This model has four important implications of how real and relative wages of high and low skilled workers respond to changes in the number of workers and changes in technology:

1. Real wages with respect to the fraction of high-skilled workers: $\frac{\partial w_L}{\partial (N_H/N_L)} > 0$, real wages of low-skilled workers increases as the fraction of high-skilled workers increases. This result comes from the imperfect substitution between high and low skilled workers, i.e., high and low skilled workers are $q$-complements. $\frac{\partial w_H}{\partial (N_H/N_L)} < 0$, real wages of high-skilled workers fall as the fraction of high-skilled workers increases.

2. Real wages with respect to technology changes: $\frac{\partial w_L}{\partial A_L} > 0$ and $\frac{\partial w_L}{\partial A_H} > 0$, real wages of low-skilled workers increase with increases in either type of labor augmenting technology. Similarly, $\frac{\partial w_H}{\partial A_L} > 0$ and $\frac{\partial w_H}{\partial A_H} > 0$.

3. Relative wages with respect to the fraction of high-skilled workers:

$$\frac{\partial \ln \omega}{\partial \ln(N_H/N_L)} = -(1 - \rho) = -\frac{1}{\sigma} < 0$$
For a given skill bias of technology, captured by $A_H/A_L$, the elasticity of the skill premium with respect to the relative supply of high-skilled workers is $-1/\sigma$. This implies a downward sloping relationship between the skill premium and the relative supply of high-skilled workers.

4. Relative wages with respect to technology changes:

$$\frac{\partial \ln \omega}{\partial \ln (A_H/A_L)} = \rho = \frac{\sigma - 1}{\sigma}$$

For a given relative supply of high-skilled workers captured by $N_H/N_L$, the elasticity of the skill premium with respect to the skill bias of technology is $(\sigma - 1)/\sigma$. When high and low-skilled workers are gross complements, $\sigma < 1$, there exists a downward sloping relationship between the skill premium and skill biased technical change. When high and low skilled workers are gross substitutes, $\sigma > 1$, there exists an upward sloping relationship between the skill premium and skill biased technical change.

Since implication 4 depends on the elasticity of substitution between high and low skilled workers, to close the model and have a definitive relationship between the skill premium and technical changes an estimate of the elasticity is needed. Most commonly authors are interested in the college premium so $\sigma$ is taken to be the elasticity of substitution between college graduates and high school graduates.

2.1 Estimation of $\sigma$

Since the CES framework is a simple and tractable model many authors have used equation (4) as a basis to estimate the elasticity of substitution between high and low skilled workers. Katz and Murphy (1992) use (4) as a starting point to estimate the elasticity
of substitution. Since \( \alpha, A_L \) and \( A_H \) capture demand shifts (4) can be written as:

\[
\ln \left( \frac{w_{Ht}}{w_{Lt}} \right) = \frac{1}{\sigma} \left[ D(t) - \ln \left( \frac{N_{Ht}}{N_{Lt}} \right) \right]
\]

where \( D(t) \) is the log-relative demand for high-skilled workers. This equation implies that for a given \( \sigma \), relative demand shifts can be estimated using relative wages and supply of high-skilled workers. To estimate \( \sigma \), Katz and Murphy (1992) replace the relative demand with a simple time trend, implying that the relative demand for high-skilled workers grows exponentially. The empirical model is:

\[
\ln \left( \frac{w_{Ht}}{w_{Lt}} \right) = \gamma_0 + \gamma_1 t + \gamma_2 \ln \left( \frac{N_{Ht}}{N_{Lt}} \right) + \varepsilon_t \tag{5}
\]

where \( \gamma_2 \) provides an estimate of \( 1/\sigma \). Katz and Murphy use CPS data from 1967-1987 to estimate (5) using OLS. Since the composition of the labor force changes over time the relative supply of college educated workers is composition adjusted. This specification results in an estimate \( \hat{\sigma} = 1.41 \), implying that high and low skilled workers are gross substitutes. Relating back to implication 4, this implies that for a given relative supply of high-skilled workers, skill biased technical change increases the college premium.

This simple model can be used to capture the effects of skill biased technical change in a tractable way. Its four implications on real wages and the skill premium are testable using data on college and high school educated workers and has often been used as the starting point for many empirical models. The next section summarizes recent labor market trends and compares them to these four implications. As will be shown, the model does well in explaining trends in the skill premium until the early 1990’s.
3 Labor Market Trends

This section summarizes recent labor market trends. The first trend analyzed is the college premium and how it has evolved over the past four decades. The second set of trends analyzed are the trends of real wages for different education groups. Throughout I will compare what is seen in the data to the simple CES model introduced above specifically how well its four implications hold up in the data.

3.1 The College Premium

The college premium is a summary measure of the market’s valuation of skill. A crude yet useful way to approach this statistic is to assume there exist only two types of workers in the market, high-skilled and low-skilled, and identify these types as workers with a college education and workers with a high school education, respectively. Implication 3 from the simple CES model predicates that the college premium is decreasing in the relative supply of college educated workers. From implication 4 and the estimate of the elasticity of substitution suggesting that high and low skilled workers are gross substitutes, the model predicts that the college premium is increasing in the relative demand for college educated workers.

Since the composition of the labor force has changed throughout the past four decades comparing the college wage premium from 1968 to 2008 can be misleading if the changing shares of different subgroups based on sex, education and experience are not accounted for. Acemoglu and Autor (2011) following Katz and Murphy (1992) and others construct a series of composition adjusted log-college/high school weekly wage premium in the US labor market for 1968 through 2008 for full time, full year workers. The series is composition adjusted to ensure that the college premium is not mechanically changing.
due to shifts in gender composition, average experience or average level of schooling within college educated and high school educated workers. Figure 1 plots the series.

Figure 1

Three characteristics of the college premium warrant attention. First the college premium was at 0.68 in 2008, the highest in the sample after almost three decades of increases. Goldin and Katz (2009) show that the college premium was at its highest in 2005 since 1915 and Figure 1 clearly shows that this long term trend has continued. Second, although there has been a tremendous increase in the college premium since the 1980’s, the series has been subject to times of a downward trend as well. Through most of the 1970 the college premium was downward trending, Goldin and Katz (2009) also document a downward trend in the 1940’s. Third, there is a clear reversal of the trend toward the end of the 1970’s.

In the CES framework the “race” between the relative demand and relative supply of high skilled workers is what determines the college premium at any point in time. Goldin and Katz (2009) attribute the downward trend though the 1970’s to the large cohorts of baby boomers entering the labor market in the 1960 and early 1970’s. These cohorts were larger and more educated than previous ones. Therefore, as the CES model suggests
the relative supply of skilled workers increased faster than the relative demand for skilled
workers during this time, educing the college premium to fall. Goldin and Katz also show
that the supply of college educated workers began to slow in the 1980’s. However, Figure
1 shows a rapid and continuous increase in the college premium commencing around
1980, suggesting the relative demand for college educated works began to increase rapidly
around this time.

Autor, Katz and Krueger (1998) set out to estimate these relative demand and supply
shifts from 1940 to 1996. Using Census and CPS data to calculate the composition
adjusted relative supply of college educated workers, Autor et al. find that from 1970 to
1980 relative supply increased by 4.99 (100×log annual changes). This increase is almost
twice as large as those experienced in the previous three decades. The 1970’s supply
increase was followed by two decades of smaller increases: 2.5 from 1980 to 1990 and 2.4
from 1990 to 1996. Using these relative supply changes, the estimated elasticity from
Katz and Murphy (1992), ̂σ = 1.41, and data on changes in the log-ratio of the wage bill
share of college graduates, Autor et al. calculate the implied demand changes with,

\[ D(t) = \ln\left(\frac{w_{HI}N_{HI}}{w_{LI}N_{LI}}\right) + (σ - 1) \ln\left(\frac{w_{HI}}{w_{LI}}\right) \]

which can be derived using (4). The implied increase of the relative demand for college
educated workers was 2.2 (100×log annual change) from 1940 to 1970 and 3.6 from 1970 to
1996. Autor et al., among others in the literature argue that the spread of computers and
information technologies was behind this increase in relative demand for college educated
workers.

Autor et al. (1998) use data from the MORG files of the CPS between 1979 and 1993
to calculate the annual change in the fraction of workers employed in 4 education groups:
college, some college, high school, and less than high school. Using data on the annual
fraction of workers who used a computer, calculated from the 1984 and 1993 October CPSs, they show that shifts toward more educated and away from less educated workers were stronger in industries that experienced a greater rise in computer use. Although this exercise shows that increased computer use and shifts toward higher educated workers are correlated it does not necessarily imply that increased computer use caused these shift.

Although many authors have argued that computers are the catalyst behind shifts way from less educated workers and toward college educated workers, few have explored what it is that computers do that could cause such shifts. Autor, Levy and Murnane (2003) (ALM) set out to answer this question. They propose that computers substitute for workers performing routine tasks, those that can be accomplished by following explicit rules, and complement workers in performing non-routine tasks. They propose a task based model in which there are four different tasks that workers can perform. (1) Routine interactive and analytical tasks such as book keeping, calculations, or repetitive customer service. (2) Routine manual tasks such as sorting or repetitive assemble. (3) Non-routine interactive and analytical tasks such as managing or hypothesis forming/testing. (4) Non-routine manual tasks such as cleaning or driving. ALM propose that computers are substitutes for tasks (1) and (2), complements to task (3), and are neither substitutes for nor complements to task (4).

Autor, Levy and Murnane (2003) use the Dictionary of Occupational Titles to approximate which occupations fall into each task category. They find that within industries, computer investment was negatively correlated with routine cognitive task input and positively correlated with non-routine analytical and interactive task input. Within education groups, increased computer usage shifted tasks performed by workers away from routine and toward non-routine tasks. These shifts were only significant for high school graduates.
and workers with some college education. The insignificant result for college educated workers can be attributed to the fact that they were most likely already performing non-routine analytical and interactive tasks. Within occupations, increased computer usage was positively correlated with non-routine interactive and analytical tasks and negatively correlated with routine cognitive tasks. Using the estimated amount of task changes within industries, education groups and occupations Autor, Levy and Murnane estimate that about 25 to 65 percent of the increases in the relative demand for college educated workers can be attributed to computerization over the past three decades.

3.2 Relative Demand Slowdown?

The simple CES model does well modeling the college premium until the early 1990’s, after which the relative demand for college skilled workers seems to be slowing. Autor et al. (2008) forecast the college premium using the elasticity of substitution estimated by Katz and Murphy (1992), \( \hat{\sigma} = 1.41 \), past the original sample (1968-1987) to 2005. The projected college premium is close to the observed college premium until 1992, after which the forecast drastically overestimated the increase in the college premium. The observed increase in the college premium after 1992 only rises by 12 log points whereas the forecast rises nearly 25 log points.

Autor et al. (2008) reestimate the same model, (5), over the full sample, 1968-2005, and find an estimated elasticity of substitution of \( \hat{\sigma} = 2.43 \) and an estimated annual trend growth of the college premium of 1.8%. This is lower than the estimated annual growth rate of the college premium estimated by Katz and Murphy, 2.6%. Allowing for a trend break in the annual growth rate in 1992 resolves the inconsistencies and results in an elasticity and annual trend growth rate consistent with those estimated by Katz and
Murphy. However the estimated trend growth of the college premium after 1992 is 1.8%, implying a decrease of about 30%.

Card and DiNardo (2002) argue that this decrease in the annual growth rate of the college premium during a time in which the growth of computer investments continued rapidly is inconsistent with the story of skill biased technological change. They propose that the rapid increase in the college premium in the 1980’s was a periodic event driven by the declining real value of the minimum wage. Autor et al. (2008) condition on the real minimum wage and unemployment rate over the sample and find that the results are robust to the argument that the declining real minimum wage was the driving force behind the rapid increase in the college premium in the 1980’s. However this still leaves the question of why the simple CES framework suggests a relative demand slowdown around the early 1990’s unanswered. Autor Katz and Kearney also point out three other striking labor market trends that are unexplainable by the simple CES model: rising inequality within and between skill groups, wage polarization and job polarization.

3.3 Rising Inequality Within and Between Groups

Although the college premium is a good initial measure of the market’s valuation of skills, its main limitation is that changes in the real wages of workers with different education levels are masked. For example, the increase in the college wage premium can arise from three different cases of real wage changes: (1) both real wages of college educated and high school educated workers are rising, but the college wage is rising at a faster rate, (2) both real wages are falling, but college wage is falling at a slower rate, (3) college wages are rising while high school wages are falling. To further understand the changes of wages across educational groups it is necessary to look at the changes of real wages. Acemoglu

Figure 2: Real Wages

There are two striking trends that Figure 2 brings to light. First, for males the rise in the college premium starting the early 1990’s is driven more so by rising wages of post-college educated workers than by workers with just a college education. Real wages for worker with post college degrees have increase steadily since the beginning of the 1980’s, whereas real wages for college graduates increased in the 1980’s, stayed fairly steady through the 1990’s with a sharp increase around 1997 and plateaued thereafter. Female wages follow a similar pattern but less pronounced. The CES model cannot explain the differential inequality within college educated and non-college educated workers.

Second, the rise in the college premium beginning in the 1980’s was in part driven by the falling real wages of males with low education levels. Real wages for males with less than a college degree decreased from their highest levels in the early 1970’s through the mid 1990’s and have plateaued since. Low-skilled females have faired slightly better; their real wages stayed fairly steady through the late 1990’s followed with small increases.
beginning in 1997 and plateauing thereafter. Again the CES model cannot explain why within the low-skilled group male workers experienced decreases in their real wages while female workers have experiences slight increase or no change. Implication 1 and 2 only allow for decreases in the real wages when the relative supply of high-skilled workers decreases or demand for low-skilled workers decrease; however, these shifts would affect all low-skilled workers as the simple CES model does not differentiate between types of low-skilled workers.

One potential problem with interpreting these results is that the decline in real wages of low-skilled workers masks a rise in their total compensation after considering non-wage payment from an employer such as health care benefits, vacation time or sick days. Pierce (2001) uses the Employment Cost Index, which covers a large part of the workforce and has cost information on may benefits components of compensation and cost of wages, to see how total compensation inequality faired from 1981 to 1997. Pierce estimates the growth in the relative compensation at the 90/10 percentiles in the compensation distribution was about 2-3 percentage points greater than the growth in relative wages. From 1982 to 1996 jobs paying wages above the median experienced large increases in health care costs, while jobs paying wages below the median saw decreases in their health care costs. This evidence casts doubt on arguments that total compensation of low skilled workers was rising during the time their real wages were declining.

This trend of rising inequality between skill groups and within skill groups commencing in the early 1990’s is a prominent feature of the U.S. labor market. From Figure 2 it is also clear these trend are more pronounced among men than women. The simple CES model cannot explain these trends in inequality and why they are more pronounced among different demographic groups.
3.4 Wage Polarization

The previous section has looked at wage inequality within and between groups. To get an idea of how overall wage inequality has changed over the past four decades it is useful to examine wage growth over the distribution of wages. Looking at the upper-tail and lower-tail wage inequality across the distribution of wages clearly shows that wage growth has polarized over since the 1990’s. Autor et al. (2008) plot the upper-tail, summarized by the 90/50 log wage gap, and the lower-tail, summarized by the 50/10 log wage gap, for males using data from the March CPS and the May CPS from 1963 to 2005. Figure 3 shows that the upper and low tails of the wage distribution begin to diverge in the early 1990’s. The upper-tail continues to grow to about 0.85 log points in 2005 whereas the lower-tail grows rapidly until 1987 after which the series plateaus around 0.8 log points. The series using the May CPS actually shows a decline in lower-tail inequality in the 1990’s. These divergent trends imply that wages for the most skilled workers and least skilled workers rose relative to those in the middle of the skill distribution. This implies that wage growth has been polarized to the upper and lower ends of the skill distribution. Since the simple CES model only has high and low skilled workers it fundamentally cannot accommodated a setting in which wage growth polarizes.

Figure 3: Upper and Lower Tail Inequality
Card and DiNardo (2002) suggest that the declining real value of the minimum wage during the 1980’s is the driving force behind rising wage inequality during this time and argue that this was an episodic event and not a trend educated by the rapid spread of computers. Autor et al. (2008) argue that the declining real value of the minimum wage can explain the dispersion of wages in the lower half of the wage distribution (as seen in Figure 2a) but it does not explain why wages of middle skilled workers have not risen relative to those of low skilled workers since 1987. The minimum wage argument also cannot explain the steady growth of wage dispersion in the upper half of the distribution that has been an ongoing trend over the past 25 years.

3.5 Job Polarization

Job polarization has been a feature of the recent U.S. labor market concurrent along with wage polarization and rising inequality within and between skill groups. Job polarization is characterized by the growth in the employment share of high-skilled, high wage occupations and low-skilled, low wage occupations. Job and wage polarization have been also been concurrent features of labor markets in many other industrialized countries (Goos et al., 2009).

Goos and Manning (2007) first find evidence of job polarization and wage polarization in the UK from 1975 to 1999. They argue that if the routinization hypothesis proposed by Autor et al. (2003) is true, then the demand for high skilled jobs and the demand for low skilled jobs should be rising relative to the demand for middle skilled jobs. Following this argument, Autor et al. (2008) use data on task intensity from the Dictionary of Occupational Titles and data on skill level by occupation in the 1980 Census to plot the task intensity by occupational skill. They find that abstract task intensity is monoton-
cally increasing in skill and manual tasks are monotonically decreasing in skill. Routine
tasks use is highest around the middle of the skill distribution, between 20th and 60th
percentiles. This non-monotonic relationship is important since routine task input saw
the largest declines from 1980 to 2000, suggesting that substitution away from routine
tasks contributed to polarization by reducing demand for middle-skilled jobs.

Autor, Katz and Kearney argue that if the changes in the wage structure in the 1980’s
and 1990’s is indeed driven by demand shifts away from routine tasks then wage changes
by earnings level and employment changes by skill level should be positively correlated.
To test this hypothesis they construct a series of log changes in the total hours worked
in the economy from 1980 to 1990 and 1990 to 2000 by occupation skill percentile as the
left hand side variable in:

\[ \Delta E_{p\tau} = \alpha_\tau + \beta_\tau \Delta \ln W_{p\tau} + \varepsilon_{p\tau} \]

where \( \Delta \ln W_{p\tau} \) is the change in real log hourly earnings at percentile \( p \) and decade \( \tau \).
Autor et al. estimate \( \beta_\tau \) = 3.00 in the 1980’s and \( \beta_\tau \) = 2.96 in the 1990’s. This implies
that both the monotonic rise of wage inequality in the 1980’s and subsequent polarization
are mirrored by changes of employment by skill and consistent with the demand side
explanation provided by ALM.

The employment growth in the upper skill quartiles is consistent with conventional
view of skill biased technical change, however the growth in the lower quartile is more
mysterious. Autor and Dorn (2013) find that the rise in employment share of lower skilled
jobs is almost entirely driven by growth in the service sector. They show that service
occupations increased as a share of aggregate employment beginning in the 1980’s. This
increase overtook the decreasing shares of all other occupations in the lowest skill quartile
in the 1990’s, netting out to increases in the aggregate share of employment of the lowest
skill quartile. They propose a model in which the continuously falling price of computers causes low-skilled workers to flow from goods production to services if the elasticity of substitution in consumption between goods and services is lower than the elasticity of substitution in production between computer capital and routine labor. Testing this hypothesis, Autor and Dorn find that commuting zone that were historically specialized in routine intensive occupations saw large increase in computer investment and large increases in the employment share of service occupations.

This section has summarized three prominent features of U.S. labor markets over the past four decades: rising within and between skill group wage inequality, wage polarization and job polarization. Each feature is consistent with the routinization hypothesis proposed by Autor, Levy and Murnane but the simple CES model cannot explain these trends. Several authors have suggest richer frameworks in which advances in information technologies is factor replacing instead of factor augmenting. The next section briefly describes two of these models.

4 A Richer Framework

The previous sections have shown that the simple CES framework is not rich enough to account for the recent trends in the U.S. labor market. Several authors have tried to adjust the model to allow for information technologies to be factor replacing, that is, the mapping from skills to tasks is no longer one-to-one as it is in the simple CES model. Common among both models is the distinction between tasks and skills.

Acemoglu and Autor (2011) propose a Ricardian model for the labor market. There are three distinct types of workers, low, middle and high-skilled and a continuum of tasks
aggregated into a final good. Each task, $i$, has a production function:

$$y(i) = A_L \alpha_L(i)l(i) + A_M \alpha_M(i)m(i) + A_H \alpha_H(i)h(i) + A_K \alpha_k(i)k(i)$$

where the $A$ terms represent factor augmenting technologies and $\alpha_L(i)$, $\alpha_M(i)$ and $\alpha_H(i)$ represent the productivity of low, middle and high skilled workers in performing task $i$. Each task can be performed by low-skilled, middle-skilled, high-skilled or capital but the comparative advantages of skill groups differ across tasks. In this setting an increase in $A_H$ corresponds to high skilled biased technical change and generates an expansion of the set of tasks in which they hold a comparative advantage; therefore, increasing the range of tasks they perform. Acemoglu and Autor argue that this model is better suited to capture the recent changes of the labor market because changes in technology alter the amount of tasks performed by different skill groups.

Jung and Mercenier (2013) build a model in which there are only three distinct tasks, routine, non-routine cognitive and non-routine manual and a continuum of skills. There are two goods in the economy, a manufactured good that uses both routine and non-routine cognitive task inputs and a service good that requires only non-routine manual task input. In this framework changes in technology induce workers to endogenously reallocate to different tasks and the range of skills allocated to each task changes. Jung and Mercenier also allow for a second order effect of technological change. First when technical change is strongly biased against routine tasks workers reallocate way from routine tasks, second productivity of non-routine cognitive tasks increases, inducing more workers to reallocate toward non-routine cognitive tasks.

This was a very brief description of two new models introduced to deal with factor replacing changes in technology. These models have gotten more attention recently when discussing the effects of technology over the past two decades. Since it is well established
at this point that information technologies and the introduction of computers has had different effects than the typical factor augmenting changes in technology these models will continue to become more prevalent in the literature. Undoubtedly such models will become the basis for estimating the effects of factor replacing technologies.

5 Discussion

At this point it seems to be well established that the falling price of computers and information technologies has had an impact on the labor market. Wage polarization has been concurrent with job polarization and evident in the U.S. and several European countries. Many papers have documented the large decrease in the employment share of routine jobs over the past two decades but few have investigated which type of routine workers are most affected by job polarization.

Cortes (2013) uses the model developed by Jung and Mercenier (2013) to predict and estimate the mobility of workers employed in routine jobs. He finds that occupational mobility of routine workers shows strong evidence of selection on ability. Routine workers with relatively high ability were more likely to switch to non-routine cognitive occupations while routine workers of relatively low ability were more likely to switch to non-routine manual occupations. Cortes also finds that over long horizons workers who switched from routine to non-routine occupations experienced faster wage growth than non-switchers.

This leads to many other questions that could be asked about the types of workers affected by polarization. Do older workers within routine occupations have a lower probability of switching to other occupations than younger workers? Since older workers may have to take a significant pay cut to switch occupations and their remaining time in the labor market may not be long enough to make up this loss through faster wage growth
they might be less likely to switch occupations than younger workers. This could lead to
another interesting question: within the group of older workers, do those that switch to
non-routine occupations stay in the labor market longer than those that did not switch?

It would also be interesting to look at how unemployment rates over the business
cycle have changed due to polarization. For instance, if we look within an industry that
is IT-intensive do unemployment rates over the business cycle vary more for middle skilled
workers in that industry than for high and low skilled workers? Or at least more so than
within an industry that is not IT-intensive?

The diffusion of information technologies and computers can explain the loss of middle
skilled jobs and declining relative wages of middle skilled workers. However, looking back
at Figure 2, one question remains unanswered: why are post college wages growing so
much faster than college wages? The skill biased technological change story implies
computers are complements to highly educated workers, but perhaps this is not the only
thing driving demand for post college educated workers. If we assume that many of
these individuals (such as engineers) are working in industries that produce information
technologies and computers, then an increase in demand for new information technologies
could be a source of rising inequality within high-skilled workers. It would be interesting
to see how much of the increases in the relative wages of post college to college educated
workers is driven by workers within IT-producing industries.

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