Wage Inequality and the Rise of Services*

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Areendam Chanda
Louisiana State University

Carl-Johan Dalgaard
University of Copenhagen and EPRU

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*Email: achanda@lsu.edu


1 Introduction

In many developed economies wage inequality has risen considerably in the last quarter of the twentieth century. An interesting facet of this observed rise in inequality is the role of skill differentials. For example, the wage premium in the US for college graduates relative to high school graduates rose from 1.35 in 1975 to 1.5 in 1985 to 1.75 in 1995 – despite increases in supply of college graduates. During the recent decade the skill premium seems to have stagnated, but remains at a much higher level than in the early 70s. Figure 1 (Autor, Katz and Kearney, 2004) shows the trends in income inequality and in particular the college-high school wage gap since 1963. As the figure highlights, the bulk of the increase took place between 1979-1992. To reconcile an increasing relative price with expanding relative supply, a sufficiently large increase in relative demand is required. Bound and Johnson (1992) and Katz and Murphy (1992) drew attention to the important role of the “demand” for more educated and skilled workers in driving these patterns. Kreuger (1993) suggested that the advent of the computer has had a role to play in these changes. This initial research gave rise to the extensive literature on skill biased technical change (henceforth, SBTC). The empirical literature has also been accompanied by a large theoretical literature on both the origins and consequences of SBTC, e.g. see Acemoglu (1998), Caselli (1999), Galor and Moav (2000) and Galor and Tsiddon (1997).

A major stumbling block, however, for theories that rely on accelerating technological change is the contrary and equally well documented observation that major developed economies in the world experienced what is commonly referred to as “the productivity slowdown” during the same period where the skill premium soared. The productivity slowdown is usually attributed to a decline in total factor productivity (TFP), primarily in the service sector. Moreover, the recent surge in growth witnessed in e.g. the US economy from 1995 onwards, have not been associated with an increasing skill premium. That is, even though “computerization” (the usual indicator of skill biased technical change) has accelerated during the same nineties (Autor, et. al., 2004). Interestingly, recent research indicate that increasing TFP growth in the service sector, possibly associated with computerization, may be responsible for reversal of the dismal growth performance of the 70s, 80s and early 90s (Bosworth and Tripplet, 2002).
Figure 1: Source: Autor, Katz and Kearney (2004)
In this paper we present a simple model which is capable of bringing these facts together in a coherent way. That is, an increasing skill premium being associated with a deceleration in growth, in turn caused by weak underlying productivity growth in service occupations. More precisely, the theory builds on two fundamental elements.

The first element derives from the work of Wallis and North (1986), who argued for a fundamental distinction between “transaction activities” and “transformation activities”. Whereas transformation activities are those related to the actual production of goods, such as work on an assembly line, transaction activities are not. Transaction activities are costs associated with running/maintaining the firm and selling the goods. Accordingly, obvious examples include legal departments, accounting, marketing, the human resource department and so on. Even within manufacturing the share of total employment deriving from such occupations has risen considerably. Wallis and North document that it increased from 15% to 38% during the period 1870-1970.

We model this distinction in a simple way by assuming that transaction and transformation activities are combined, in some fixed relation, to produce output. Accordingly, both “tasks” are necessary to produce final output.

The second element derives from the work of Baumol (1967), who argued that services is a technologically backward sector. Observing the close link between Wallis and North’s concept of “transaction activities”, and the more conventional notion of “services”, provides the motivation for assuming that transaction activities tend to be less productive, in the sense of total factor productivity (TFP), than transformation activities.

Against this background, and unlike in other macroeconomic theories, we essentially employ the notion of Baumol’s (1967) curse as part of an explanation for the increasing wage inequality. A temporary drop in TFP in transaction activities causes the productivity slow down. Both in terms of income per worker, and in terms of aggregate TFP. Moreover, as long as the skill intensities in transformation and transaction activities are sufficiently dissimilar, with transactions being more skill intensive, such unbalanced growth (even if temporary) will have long term consequences for wage inequality. In particular a slowdown in TFP in the transaction activities will increase the wages of skilled labor more than the wages of the unskilled sector.

Whereas the work of Baumol (1967) suggest that transaction activities ul-
timately may be less productive than transformation activities, one may argue that computers have led to surge of TFP growth within transaction activities (Bosworth and Tripplet, 2002). In this case, our model predicts a reversal of growth and inequality trends; a surge in growth accompanied by a falling, or at least unaltered, skill premium.

Our long run intention is to calibrate the model to match the US data for the last three decades of the twentieth century. In particular it matches better the main challenges that proponents of skill biased technological change face. That is: (a) the productivity slowdown coincided with increasing inequality in wages; (b) The post 1995 productivity resurgence has, if anything, coincided with a possible stabilization of wage inequality; (c) the increasing recognition by labor economists that occupational inequality may be as important as educational based wage inequality in explaining what happened over the past few decades (Eckstein and Nagypal, 2004).

The model is extended to consider the implications of changes in the production function’s parameter (i.e. the seriousness of Baumol’s curse), endogenous skill formation and occupational choice. We next discuss the evidence on service sector and the general evidence on TFP growth.

2 The Productivity Slowdown and the Service Sector

The fact that labor productivity in the US went through an extended slowdown from 1973-1995 is now well universally documented and despite several attempts to correct for possible measurement errors. Despite a number of hypotheses, there does not exist yet a satisfactory answer for what happened. Indeed one such hypothesis presented by SBTC advocates is the fact that the introduction of new technologies led to an extended period of “adjustment” during which skills increase in demand leading to both a slowdown and an increase in inequality. Greenwood and Yorokoglu (1997) is an example of this kind of a theory. Thus both features of the past 25 years can be explained. One might wonder though if it takes 25 years to learn a new technology. In this section we review the evidence on the productivity slowdown and in particular the role of the service sector. The existing literature is very large and as in any other research, there is considerable disagreement amongst the researchers as there are
ways of measuring the slowdown. Steindel and Stiroh (2001) provide a useful summary of the state of the literature. Table 1 below corresponds to Table 2 in their paper. The table presents estimates made by the Bureau of Labor Statistics and two well influential studies, Jorgenson and Stiroh (2000) and Oliner and Sichel (2000). If one focusses on the fourth row which informs us of the growth rate in labor productivity it is evident from these that a sharp upswing took place post 1995 and more importantly this was accompanied by a sharp upswing of total factor productivity (in addition to capital deepening).

The obvious question that arises for our hypothesis is what exactly happened to the service sector vis a vis the rest of the economy. The observation that service sector in particular recorded low productivity growth during the period of productivity slowdown has been at the center of this literature for a long time. Jorgenson (1996) notes that the manufacturing sector did quite well. To see the difference consider Table 2 (taken from Steindel and Stiroh (2001)). The table shows the pre productivity slowdown growth and also lists the manufacturing sector’s estimates. Confirming Jorgenson’s observations there is little evidence that manufacturing actually went through much of a slowdown- given that non farm business sector’s growth rate did decelerate this must mean that most of the decline actually did take place in the service sector. Thus the frequent reference to “Baumol’s Disease” in the literature. Recent work for example by Tripplet and Bosworth (2001) continue to document this despite attempting to correct for measurement errors. Further Steindel and Stiroh (2001) note that since most of the service sector’s output is actually an intermediate input, it is unlikely that the mismeasurement itself can create significant mismeasurement issues at the

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<tr>
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<td>3.0</td>
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<td>1.9</td>
<td>3.04</td>
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<tr>
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<td>2.5</td>
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<td>1.62</td>
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<tr>
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<td>2.3</td>
<td>0.9</td>
<td>1.42</td>
<td>2.58</td>
<td>1.16</td>
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<td>0.85</td>
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<td>0.77</td>
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<tr>
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<td>0.1</td>
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<td>0.01</td>
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<tr>
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<td>0.9</td>
<td>0.34</td>
<td>0.99</td>
<td>0.65</td>
<td>0.36</td>
<td>1.16</td>
<td>0.80</td>
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Notes: ALP Contributions are defined in Equation (1). All values are percentages. BLS estimates for nonfarm business sector through 1998 and numbers do not add precisely due to rounding.

aggregate level. Finally as Tripplet and Bosworth (2001), argue, it is difficult to reason why the service sector should have suddenly seen mismeasurement appear in 1973.

The next observation that we document is the acceleration of service sector in MFP. This is best documented in recent work of Tripplet and Bosworth (2002) where they forcefully argue that service sector MFP accelerated after 1995. Further they note that the most intensive adopters of information technologies have been the service sector industries during this period. Thus the revival of MFP growth has coincided with growth in the service sectors leading them to argue that Baumol’s disease has been cured.

The final piece of evidence that we would like to present is related to the skilled ratio of the service sector relative to manufacturing. A critical assumption of our story is that service sector is more skill intensive compared to the rest of the economy (in particular manufacturing). Is this a valid assumption.
Figure 4:

Figure (2) presents some supporting evidence based on educational attainments. We define the unskilled as anyone with a high school degree or less. The figure lists the ratios for various subsectors of the economy in 2001. We list the two main non agricultural and non service sectors- manufacturing and construction and a number of service sectors and the overall service sectors. As can be seen from this diagram, that in the service sector around 65% of the population has some college or more. In the manufacturing sector, the share is 50% and in construction it around 35%. There are of course disparities within the service sector- more traditional sectors like trade and transportation are more like manufacturing while the rest are not. Within manufacturing there is much less discrepancy with only electronics and chemicals sectors showing a very high skill intensity. Overall our assumption of the differences in skill ratios seem valid.
3 A Simple Model

We are considering a closed economy, time is continuous and extends into the infinite future. The economy produces a homogenous good which can be either consumed or invested. The market for the final good and production inputs are competitive.

The labor force comprises both skilled and unskilled labor. The relative supply is exogenous and constant over time. The labor force itself grows at the constant rate \( n \).

Households save a constant fraction of their income \( s \) each period. Accordingly, wage inequality, which arises in equilibrium, will not matter for the rate of capital accumulation. In this way we are able to focus on the impact of growth in technology on the evolution of the skill premium, and income per worker. The details are given below.

3.1 Production

The representative firm produces output, \( Y \), by combining two distinct tasks: transaction activities, \( T \), and transformation activities, \( P \), in a fixed relation \( \gamma \). That is

\[
Y = \min(P, \gamma T) .
\]  

(1)

Equation (1) captures that final goods are created by combing both explicit production activities (\( P \)), like assembly line work, with service activities of various kinds (\( T \)). The latter represents the combined contribution from divisions within firms, such as the legal department, accounting, marketing, the human resource department and so on. The Leontief specification is adopted so as to capture that both activities are essential for the procurement of final goods. Accordingly, we assume that the creation of 1 unit of final good requires the combination of 1 unit of transaction activities and \( \gamma \) units of transformation activities.

Within specific tasks substitution of inputs is possible. More specifically, transactions are produced with the following technology involving skilled labor \( L_s \) and capital, \( K_T \):

\[
T = A_T L_s^\eta K_T^{1-\eta} ,
\]  

(2)

while transformation activities uses capital and unskilled labor, \( L_u \):

\[
P = A_p L_u^\eta K_p^{1-\eta} .
\]  

(3)

8
We assume $A_p$ grows over time at the exogenous rate $g$, and that $A_T/A_p \equiv a$ is constant. Inspired by the work of Baumol (1967) we will assume that the technology used in transaction activities tend to lag that of transformation activities. Baumol’s argument was more extreme, in that he argued that services, many of which are isomorphic to Wallis and North’s notion of transaction activities, are asymptotically stagnant. That is, technology does not expand in the limit. For present purposes we shall only assume that transaction activities tend to lag transformation activities, and explore the consequences of changes in the relative level of technology. In concrete terms we assume that

$$A_T(t) = A_p(t - \tau) \iff A_T(t)/A_p(t) = a = e^{-g\tau},$$

where $\tau$ is the time lag between adoption of a technology in transformation activities and adoption of the same technology in transaction activities.

An important aspect of the production technologies is the assumption that transaction activities uses skilled workers relatively intensively. We believe this is a plausible assumption considering the type of processes we have in mind here – legal work, financial services and so on. To fix ideas we invoke the extreme assumption that transformation activities only involve skilled labor, transformation activities only unskilled labor.

Assuming that capital is fully mobile across activities within the firm, we may proceed by deriving the allocation of capital across “tasks”. Using equation (1) it follows that

$$\left(\frac{K_p}{K_T}\right)^{1-\eta} = \gamma a \left(\frac{L_s}{L_u}\right)^{\eta}. \quad (4)$$

By definition, the total stock of capital is given by the sum:

$$K = K_p + K_T. \quad (5)$$

Using equations (4) and (5) we have that the fraction of the firms total stock of capital used in transformation processes is

$$K_p/K = \frac{(\gamma a)^{1-\eta} \left(\frac{L_s}{L_u}\right)^{\eta}}{1 + (\gamma a)^{1-\eta} \left(\frac{L_s}{L_u}\right)^{\eta}}. \quad (6)$$

The interpretation of this expression is simple. If $A_T$ rises relatively to $A_p$, capital flows into transformation activities, so as to maintain $P = \gamma T$. If final
goods production becomes less transaction intensive, an upward shift in $\gamma$, then capital also flows into transformation activities.

With this information we can write down the reduced form production technology. By the Leontief assumption it follows that

$$Y = \gamma A_T L_s^\eta K^{1-\eta} \left( 1 + (\gamma a) \frac{L_s}{L_u} \right)^{\eta - 1}.$$  \hspace{1cm} (7)

where we have invoked $Y = P$ along with equation (6). Observe that the reduced form production technology exhibits constant returns to scale in $L_s, L_u, K$ combined. Compensation of capital and labor thus exhausts total output.

The firm chooses $L_s, L_u$ and $K$ so as to maximize profits $Y - w_s L_s - w_u L_u - rK$ subject to the reduced form production technology, equation (7). The factor prices are respectively: $w_s, w_u$ and $r$. The first order conditions are

$$r = (1 - \eta) \frac{Y}{K}. \hspace{1cm} (8)$$

$$w_s = \eta \left[ 1 - \frac{(\gamma a) \frac{L_s}{L_u} \left( \frac{L_s}{L_u} \right)^{\eta - 1}}{1 + (\gamma a) \frac{L_s}{L_u} \left( \frac{L_s}{L_u} \right)^{\eta - 1}} \right] \frac{Y}{L_s}. \hspace{1cm} (8)$$

$$w_u = \frac{\partial Y}{\partial L_u} = \eta \frac{(\gamma a) \frac{L_u}{L_s} \frac{L_u}{L_s}^{\eta - 1}}{1 + (\gamma a) \frac{L_u}{L_s} \frac{L_u}{L_s}^{\eta - 1}} \frac{Y}{L_u}. \hspace{1cm} (9)$$

Accordingly, capitals’ share is constant through time, and given by $1 - \eta$. Labors share is also constant, at $\eta$. But the composition of these outlays changes as $A_T, A_p, \gamma$ and the number of skilled and unskilled changes.

For future reference, it is worth noting that income per worker can be written

$$\frac{Y}{N} = \frac{\gamma A_T \left( \frac{L_s}{L_u} \right)^{\eta}}{1 + (\gamma a) \frac{L_s}{L_u} \left( \frac{L_s}{L_u} \right)^{\eta - 1}} \left( \frac{K}{N} \right)^{1-\eta},$$

where $N$ represents the total labor force, which decomposes into skilled and unskilled laborer.

$$N = L_s + L_u.$$

### 3.2 Labor Market Equilibrium

The labor market equilibrium arises when the relative supply of skilled and unskilled labor equals relative demand. Invoking the first order conditions from
the problem of the firm, equation (8) and (9), yields the following inverse relative demand function
\[
\frac{w_s}{w_u} = (\gamma e^{-g\tau})^{\eta} \left( \frac{L_{is}}{L_{is}} \right)^{\frac{1}{\eta}}. \tag{10}
\]
Thus, changes in relative technology in transaction and transformation activities will manifest itself in changing relative demand for skilled labor. Imposing the assumption that the relative supply of the two types of labor is constant over time, and given by
\[
\lambda_s \equiv \frac{L_s}{N} \quad \text{and} \quad 1 - \lambda_s = \frac{L_u}{N},
\]
we have the following equilibrium result

**Proposition 1** *Skill premium and relative technological change.* Define the skill premium as \( \omega \equiv \frac{w_s}{w_u} \). (i) \( \partial \omega / \partial \tau > 0 \). (ii) \( \partial \omega / \partial \gamma < 0 \).

**Proof.** Follows immediately from differentiation of equation (10).

The intuition for this result should be transparent. If \( \tau \) goes up (a decreases) capital flows into transaction activities so as to ensure \( P = \gamma T \). Since capital and labor are complements, the marginal productivity of the labor input used intensively in transactions, \( L_s \), rises. In other words, the associated increase in \( K_T/K \) is sufficiently large so as to compensate for the fact that \( a \) fell to begin with. Equation (6) makes this clear – a reduction in \( a \) of 1 percent leads to an reduction in \( K_p/K \) of \( 1/(1 - \eta) > 1 \) percent. This is what generates the increase in relative demand for service labor, that is, skilled labor.

A reduction in \( \gamma \) produces the same pattern of an intensified allocation of capital for transaction purposes. This sort of a structural change in the production process will therefore also impact on the skill premium.

### 3.3 Capital Accumulation

Income per efficiency units of labor is given by
\[
y = \frac{\gamma e^{-g\tau} \left( \frac{L_p}{N} \right)^{\eta}}{\left[ 1 + (\gamma e^{-g\tau})^{\frac{1}{\eta}} \left( \lambda_s/\lambda_u \right)^{\frac{1}{\eta}} \right]^{1-\eta} k^{1-\eta}} \tag{11}
\]
where \( x = X/ \left( A_p^{1/\eta} N \right) \), for \( X = Y, K \). Moreover, assuming households save a constant fraction of income, then the capital stock per efficiency unit is given by
\[
\dot{k}/k = sG(k, \tau, \lambda_s, \lambda_u) - (n + g/\eta)
\]
where
\[
\gamma e^{-g\tau} \left( \frac{k}{N} \right)^\eta \left[ 1 + \left( \gamma e^{-g\tau} \right)^\frac{1}{\eta} \left( \frac{\lambda_s}{\lambda_u} \right)^\frac{\eta}{\eta} \right]^{\frac{1}{1-\eta}} k^{-\eta} \equiv G(k; a, \lambda_s, \lambda_u)
\]

, \( g = \dot{A}_p/A_p = \dot{A}_T/A_T \), while \( n \) is the rate of labor force growth. The phase diagram for this model is for practical purposes identical to the one of the Solow model. The economy gradually approaches a unique (non-trivial) steady state, where output per worker is given by

\[
\left( \frac{Y}{N} \right)^* = \frac{(\gamma e^{-g\tau})^\frac{1}{\eta} \lambda_s}{1 + (\gamma e^{-g\tau})^{\frac{1}{\eta}} \left( \frac{\lambda_s}{\lambda_u} \right)^{\frac{\eta}{\eta}}} \cdot s^{-\frac{n}{\eta}} A_p(0) e^{\eta - 1 - g}. \tag{12}
\]

In steady state the economy grows at the constant rate of exogenous technical change, \( g/\eta \). Obviously, any change in \( s, \tau, \lambda_i \) \( i = s, u \) or \( n \), will generate a change in the level of productivity in the long run, and thus be associated with a temporary change in growth in income per worker as the economy adjusts. Therefore, of particular interest are changes in the adoption lag, \( \tau \), as well as the structural parameter \( \gamma \). Factors that also matter for the evolution of wage inequality. We have

**Proposition 2 Steady state comparative statics.** \( \frac{\partial((Y/N)^*)}{\partial a} > 0 \), \( \frac{\partial((Y/N)^*)}{\partial \gamma} > 0 \).

**Proof.** Take logs of eqs (12) (and ignore terms we keep fixed)

\[
\ln \left( \frac{Y}{N} \right)^* = \frac{1}{\eta} \ln a - \frac{1 - \eta}{\eta} \ln \left( 1 + (\gamma a)^{\frac{1}{\eta}} \left( \frac{\lambda_s}{\lambda_u} \right)^{\frac{\eta}{\eta}} \right)
\]

Differentiate and rearrange terms to obtain:

\[
\frac{\partial \ln \left( \frac{Y}{N} \right)^*}{\partial a} = \frac{1}{\eta} \left[ 1 - \frac{\gamma^{\frac{1}{\eta}} a^{\frac{1}{\eta}} \left( \frac{\lambda_s}{\lambda_u} \right)^{\frac{\eta}{\eta}}}{1 + (\gamma a)^{\frac{1}{\eta}} \left( \frac{\lambda_s}{\lambda_u} \right)^{\frac{\eta}{\eta}}} \right] > 0
\]

Hence, if \( \tau \) increases (\( a \equiv A_T/A_p \) declines) Income per worker declines. Changing \( \gamma \) is a completely symmetrical exercise.

The phase diagram depicted in Figure 1 shows this result geometrically for a scenario where \( \tau \) rises (\( a \) declines) or \( \gamma \) increases (transaction intensity rises).

If \( a \) declines the long run level of income per worker shifts down. In transition therefore, growth in income per worker declines. By Proposition 1 we
know that the same change will entail an increasing skill premium. Hence, if the productivity of transaction activities declines relative to transformation activities the economy will simultaneously experience rising wage inequality, and a (temporary) productivity slowdown. The productivity slowdown will in fact be associated with aggregate TFP, suitably defined. To see this, note that equation (7) can be restated to yield

\[ \frac{Y}{N} = TFP \cdot \left( \frac{K}{N} \right)^{1-\eta}, \]

where

\[ TFP = \frac{\gamma a \left( \frac{L_s}{N} \right)^{\eta}}{1 + (\gamma a)^{1-\eta} \left( \frac{L_s}{L_u} \right)^{1-\eta}} \cdot A^{1/\eta}. \]

It now follows that

**Proposition 3 Comparative statics: Aggregate TFP.** Define \( TFP \equiv \frac{Y}{N} / \left( \frac{K}{N} \right)^{1-\eta} \). \( \partial TFP / \partial a > 0 \) and \( \partial TFP / \partial \gamma > 0 \).
Proof. Differentiation yields immediately the result. ■

In other words, the model predict that if transaction activities fall further behind transformation activities in terms of $A$, a productivity slowdown sets in. Both in terms of aggregate TFP and income per worker. In addition, the skill premium rises.

## 4 Conclusion

In this paper we have presented an argument that suggests a causation from the decline in the productivity growth to the increase in wage inequality. The argument relies heavily on the inter sectoral differences on skill ratios, in particular the difference between the skill intensities of the service sector and the manufacturing sector. Moreover our hypothesis also matches the record in the nineties of rising productivity in the service sector and stabilizing wage inequality. However an important question remains, why did the more skill intensive sector of the economy experience an elongated period of productivity slowdown while the relatively unskilled sector not experience such an elongated period of productivity slowdown? This is clearly a central question that remains to be answered.

## References


