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Stagnation and Technological Progress

Ryoichi Imai *

Abstract

I present a simple model to illustrate the mechanism that technological progress might cause apparent stagnation, while it obviously improves economic welfare. TFP growth in the manufacturing sector induces employment and output to shift to the service sector if the elasticity of substitution in preference is small. Then GDP stagnates while welfare increases.

1. Introduction

In December 2013, Mr. Noritoshi Furuichi, a sociologist and media commentator, said:

"*Fast food chain restaurants provide social welfare service in Japanese way. In the Scandinavian countries, people pay high taxes to the government to make higher education and medical services financially affordable. With strong employment protection legislation and high minimum wages, eating out is very expensive in those countries. In Japan, however, clothing and dining are provided at affordable prices by business companies. In other words, welfare service is provided in the private sectors in Japan.*"

This comment gave rise to a controversy on the role division between government and private sectors. Some argued that Mr. Furuichi just provided a way to excuses for the government not to provide sufficient protection for socially disadvantaged people. Others argue that there should be some improvement of social capital brought by the development of service industries. In this article, I would

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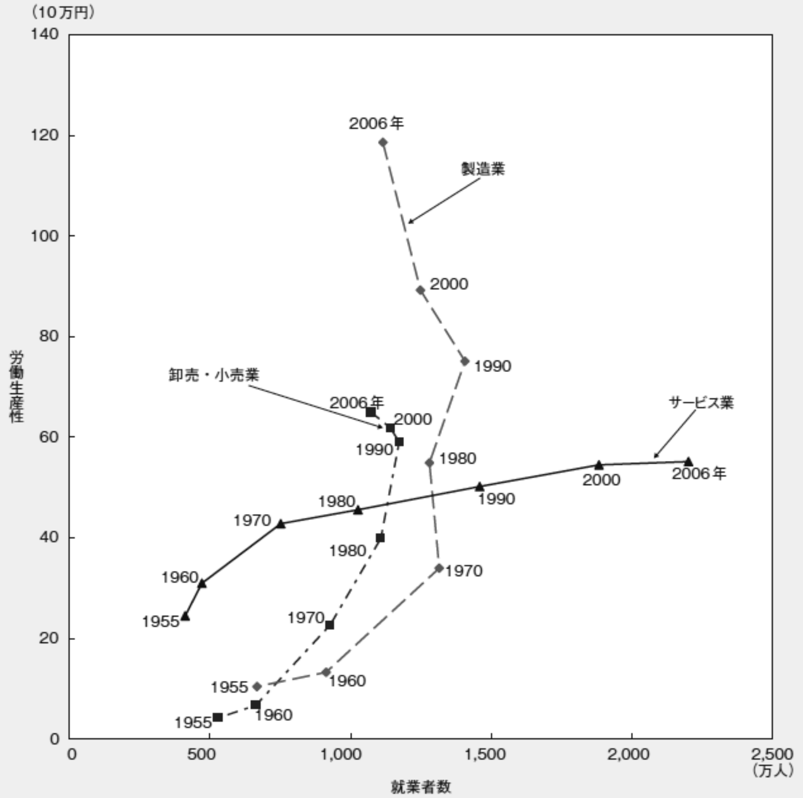
like to illustrate the mechanism that technological progress in the manufacturing sector enables households to consume more services, and improve their welfare.

Cabinet Office of Japan (2010a) reports that employment declines in those sectors in which productivity growth is fast, not only in Japan but also in the United States. Ministry of Health, Labour and Welfare (2008) points out that employment is growing in the service sectors where labor productivity growth is slow, while employment stagnates in the manufacturing sector where labor productivity growth is fast, as is illustrated in Figure 1.

As many economists have noted, GDP is a flawed measure of economic welfare. GDP is just aggregate expenses that enable households to achieve a certain level of utility, which depends not only on consumption but also on other factors such as leisure and life expectancy. Jones and Klenow (2010) propose a simple summary statistic for a nation's flow of welfare, measured as a consumption equivalent, and finds that Japan's welfare grew at two percent higher rate than that of the United States during the period from 1980 to 2000 including the "lost decade" after 1990. Discrepancy of welfare from GDP does not come only from improvement in those factors such as leisure, life expectancy, income equality, and crime rates, but also from changes in composition of consumption. The latter is the issue I focus on in this article.

Economic development is followed by sectoral change. Cabinet Office of Japan (2013) reports that manufacturing sectors shrink and more employment is created in service sectors in the advanced economies as in Figure 2. In other words, economic growth is typically unbalanced. Baumol (1967) and Baumol et al (1985) present a theory and evidences that employment and output decline in the sectors where productivity growth is fast, and increase in the sectors where productivity growth is slow. Economic theory on unbalanced growth has been recently developed by Echevarria (1997), Kongsamut et al (2001), Ngai and Pissarides (2007), and Acemoglu and Guerrieri (2008), among others. Characterization of steady states of unbalanced growth is challenging in dynamic setting. In this article I present a simple static model to illustrate the mechanism that unbalanced growth improves welfare while GDP stagnates. Consider an economy with a manufacturing sector (denoted by M) and a service sector (denoted by S), in which capital and labor move to maximize their marginal returns (rents and wages) between the two sectors. Productivity growth is usually faster in sector M than in sector S. If the elasticity of substitution between the manufacturing good and the service is sufficiently low as is usually assumed, technological progress in sector M reduces the relative price of the manufacturing good to the service, and then em-

第3－（3）－2図　就業者数と労働生産性の推移



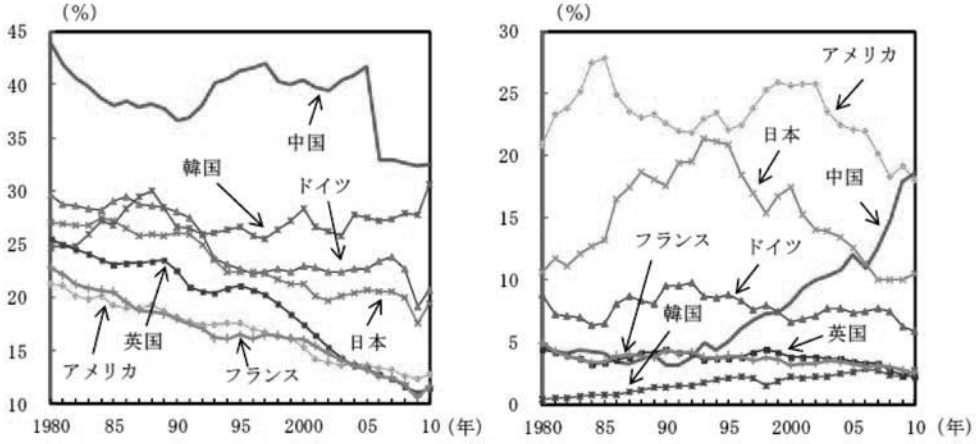
資料出所　内閣府「国民経済計算」をもとに厚生労働省労働政策担当参事官室にて推計
（注）1）労働生産性は実質国内総生産（産業別）を就業者数（産業別）で除したものとした。
2）2000年基準の値（実質・固定基準年方式）に過去の指数を接合して遡及系列とした。

Figure 1: http://www.mhlw.go.jp/wp/hakusyo/roudou/08/dl/03_0003.pdf

第３－２－２図　製造業の国内シェアと世界シェア

我が国の製造業の国内シェアの低下ペースは米独並み

（１）製造業の国内シェア　　**（２）製造業の世界シェア**



（備考）　１．UN "National Accounts" により作成。
２．製造業のシェアは、実質付加価値額ベース。
３．ドイツは、東西統合の影響により 1991 年前後のデータは整合的でない。
４．中国は、2006 年に製造業の付加価値生産額が落ち込んだ影響によって、国内シェアが大きく変動している点に留意が必要である。

Figure 2: http://www5.cao.go.jp/keizai3/2012/1222nk/pdf/12-3-2.pdf

ployment shifts from sector M to sector S. This transition is widely observed in the most OECD countries during the process of economic growth. Technological progress obviously improves economic welfare, while it might reduce value-added and employment in the sector where technological progress occurs, through a sharp decline in the relative price of the good produced in that sector.

The paper is organized as follows. In the next section, the model is presented. Section 3 presents the results and explores the implications. The paper is concluded in Section 4.

2. The Model

In this article, I would like to present a simple model to generate discrepancy between GDP and welfare measures. The model is static and highly stylized, but is enough to predict the long-run consequences of productivity growth.

The economy consists of two sectors M (manufacturing) and S (service). The representative consumer has preference over the manufacturing good and the service. The preference is of CES,

$$U = [\delta c_M^\sigma + (1-\delta)c_S^\sigma]^{\frac{1}{\sigma}} \tag{1}$$

where δ denotes the share of the manufacturing good. The elasticity of substitution between the manufacturing good and the service is given by

$$s = \frac{1}{1-\sigma}.$$

Then the elasticity of substitution s is related to σ as follows.

$$\left.\begin{array}{c} \sigma > 0 \\ \sigma = 0 \\ \sigma < 0 \end{array}\right\} \Longleftrightarrow \left\{\begin{array}{cr} s > 1, & \text{elastic} \\ s = 1, & \text{Cobb-Douglas} \\ s < 1, & \text{inelastic} \end{array}\right. .$$

The consumers' budget constraint is

$$P_M c_M + P_S c_S = wN + rK \tag{2}$$

where w is the wage rate and r is the return to capital. The labor (N) endowment is fixed at $N = 1$ and capital (K) endowment is exogenously given. The price of the service is normalized at $P_S = 1$, and the price of the manufacturing good is given by P_M. That is, the service is the numeraire.

The consumer maximizes its utility (1) subject to the budget constraint (2). The Lagrangian is written as

$$L = [\delta c_M^\sigma + (1-\delta)c_S^\sigma]^{\frac{1}{\sigma}} + \lambda[wN + rK - P_M c_M - P_S c_S]$$

The FOC for c_M and c_S are derived to get

$$P_M c_M = P_S c_S * \frac{\delta c_M^\sigma}{(1-\delta)c_S^\sigma} \tag{3}$$

The production functions of both the sectors are

$$Y_M = A_M N_M^\alpha K_M^{1-\alpha}, \quad Y_S = A_S N_S^\beta K_S^{1-\beta}$$

where $0 < \alpha < \beta < 1$, since sector M is less labor-intensive than sector S. Total factor productivity (TFP) is multiplicative as A_M and A_S. Both the labor and the capital markets are competitive, and then the wage rate and the rate to return to capital equal their marginal productivity.

$$w_M = \alpha P_M A_M \left(\frac{K_M}{N_M}\right)^{1-\alpha}, \quad w_S = \beta P_S A_S \left(\frac{K_S}{N_S}\right)^{1-\beta}$$

$$r_M = (1-\alpha) P_M A_M \left(\frac{K_M}{N_M}\right)^{-\alpha}, \quad r_S = (1-\beta) P_S A_S \left(\frac{K_S}{N_S}\right)^{-\beta}$$

The factor markets clear:

$$K_M + K_S = K, \quad N_M + N_S = N \tag{4}$$

The product markets clear:

$$c_M = A_M N_M^\alpha K_M^{1-\alpha}, \quad c_S = A_S N_S^\beta K_S^{1-\beta} \tag{5}$$

Capital and labor are allocated between the two sectors in order to equate their marginal productivity:

$$w_M = w_S, \quad r_M = r_S,$$

which gives us $k_M = \frac{K_M}{L_M}$ and $k_S = \frac{K_S}{L_S}$, the capital-labor ratios in both the sectors, as

$$\ln k_M = \frac{(1-\beta)\ln\left(\frac{P_S A_S (1-\beta)}{P_M A_M (1-\alpha)}\right) - \beta \ln\left(\frac{P_M A_M \alpha}{P_S A_S \beta})\right)}{\beta - \alpha}, \tag{6}$$

$$\ln k_S = \frac{(1-\alpha)\ln\left(\frac{P_S A_S (1-\beta)}{P_M A_M (1-\alpha)}\right) - \alpha \ln\left(\frac{P_M A_M \alpha}{P_S A_S \beta})\right)}{\beta - \alpha} \tag{7}$$

(4) implies the allocation of labor force across sectors as

$$N_M = \frac{K - Nk_S}{k_M - k_S}, \quad N_S = \frac{Nk_M - K}{k_M - k_S} \tag{8}$$

Product market clearing condition is rewritten as:

$$c_M = A_M k_M^{1-\alpha} \left(\frac{K - Nk_S}{k_M - k_S}\right), \quad c_S = A_S k_S^{1-\beta} \left(\frac{Nk_M - K}{k_M - k_S}\right) \tag{9}$$

The GDP is derived as a function of the good prices and the capital-labor ratios in both the sectors.

$$P_M c_M + P_S c_S = P_M A_M k_M^{1-\alpha} \left(\frac{K - Nk_S}{k_M - k_S}\right) + P_S A_S k_S^{1-\beta} \left(\frac{Nk_M - K}{k_M - k_S}\right) \tag{10}$$

The service is a numeraire and its price is normalized.

$$P_S = 1.$$

An equilibrium is a set $(P_M,\ k_M,\ k_S)$ that satisfy (3), (6), and (7).

3. The Results

Employment and output in both the sectors, as well as the GDP are given as functions of $(P_M,\ k_M,\ k_S)$ by (8), (9), and (10). The welfare, or the utility of the representative consumer is calculated by (1).

The model is highly nonlinear. However, comparative statics is performed by linearizing the model around equilibrium as in APPENDIX. Here I would like to numerically demonstrate how technological progress affects the relative price, the capital-labor ratios, employment, GDP, and welfare.

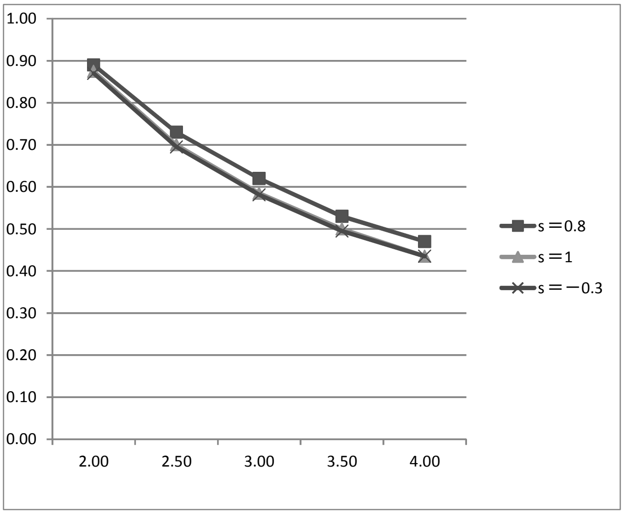


Figure 3: TFP and the manufacturing good price

The baseline parameters are

$$\alpha = .5,\ \beta = .7,\ \delta = .5,\ K = 2,\ A_S = 2.$$

I perform exercises for $\sigma = .8,\ 0,\ -.3,$ and $A_M = 2,\ 2.5,\ 3.0,\ 3.5,\ 4.0$. That is, I present some quantitative analyses on how technological progress in the manufacturing sector affects the endogenous variables, depending on the elasticity of substitution between the manufacturing good and the service.

Figure 3 shows that technological progress in sector M uniformly reduces the price of the manufacturing good. Changes in the elasticity of substitution does not make considerable difference. Technological progress reduces the price of the good in the sector where technological progress occurs.

The elasticity of substitution generates significant difference in employment as in Figure 4. The higher the elasticity of substitution is, the more employment is created in the manufacturing sector, because households consume more of the manufacturing good.

Figure 5 and Figure 6 show that the capital-labor ratio slightly rises for the two low elasticity cases, while it significantly declines for the high elasticity case. Technological progress reduces the capital-labor ratio in both the sectors if the elasticity of substitution is sufficiently high. The manufacturing sector attracts

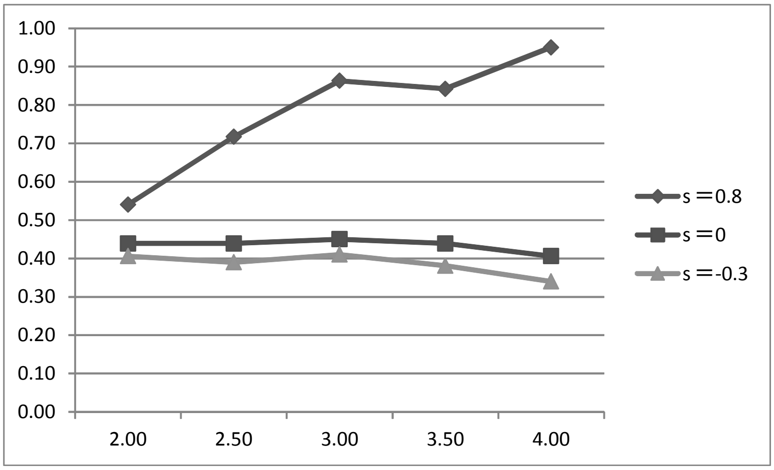


Figure 4: TFP and manufacturing employment

labor more than capital . This result is consistent with the popular story that the sector with higher productivity growth employs more labor.

Figure 7 and Figure 8 illustrate the possibility that GDP stagnates while welfare rises if the elasticity of substitution is low. It is obvious for technological innovation in the manufacturing sector to generate welfare gain. If the elasticity of substitution is high, the negative effect of the innovation on the manufacturing price is even more than cancelled by the increasing output in that sector, and GDP increases with welfare. If the elasticity of substitution is low, output in the manufacturing sector does not increase so much as to cancel the declining price impact on its value-added. GDP stagnates while welfare increases.

The exercises show that there might be discrepancy between GDP and welfare if the rate of substitution in preference is so small that technological progress in the manufacturing induces consumers to spend more in the service sector than in the manufacturing sector.

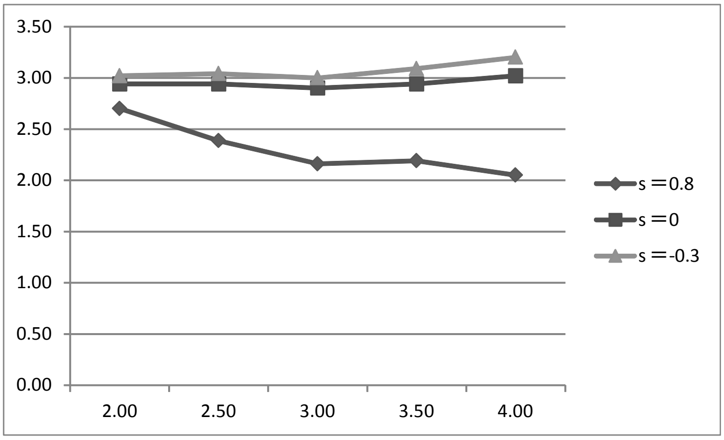


Figure 5: capital-labor ratio in manufacturing

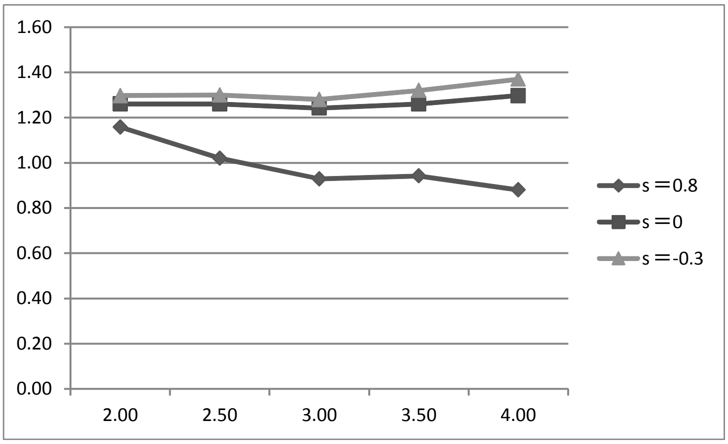


Figure 6: capital-labor ratio in service

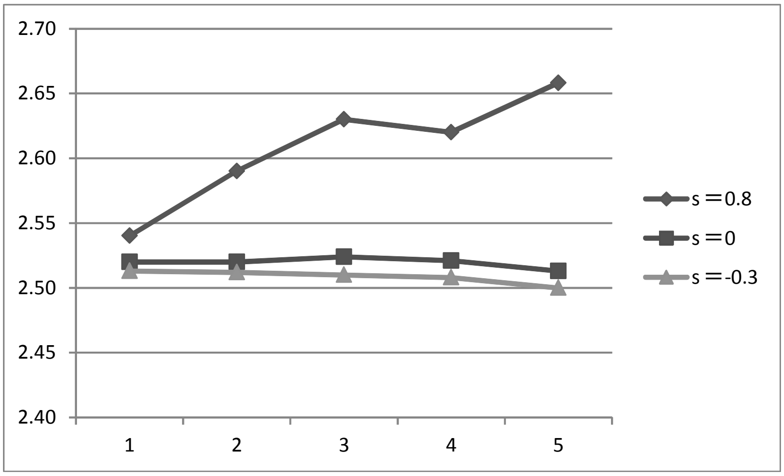


Figure 7: TFP and GDP

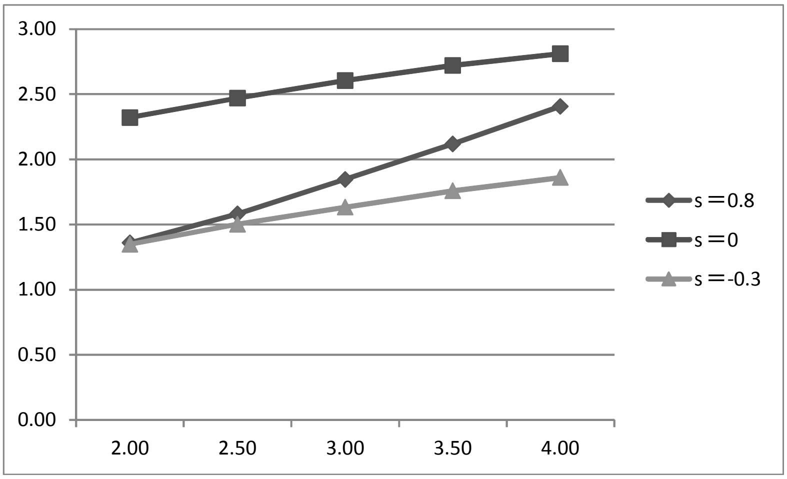


Figure 8: TFP and welfare

4. Conclusion

The paper presents a simple model to illustrate the mechanism that technological progress might cause stagnation, while it improves welfare. TFP growth in the manufacturing sector reduces its price, and induces households to consume less manufacturing goods and more services. Then the GDP share of the manufacturing sector declines and GDP stagnates.

The model can be extended to the following directions. First, we can consider a neoclassical growth model with sectoral change, although characterization of its steady states is a challenging task as in the previous literature. Second, we can consider unemployment by incorporating search friction in the model, and address the composition inefficiency of good jobs and bad jobs, as in Acemoglu (2001).

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APPENDIX 1

(3), (6), and (7) forms a system with three endogenous variables $(k_M,\ k_S,\ P_M)$,

$$k_M = F(P_M), \quad k_S = G(P_M), \quad P_M = H(k_M,\ k_S)$$

which has a recursive structure and uniquely solved for P_M. The system is linearized as follows.

$$dk_M = \frac{\partial F}{\partial P_M} dP_M + \frac{\partial F}{\partial x} dx$$
$$dk_S = \frac{\partial G}{\partial P_M} dP_M + \frac{\partial G}{\partial x} dx$$
$$dP_M = \frac{\partial H}{\partial k_M} dk_m + \frac{\partial H}{\partial k_S} dk_S + \frac{\partial H}{\partial x} dx$$

or,

$$\begin{pmatrix} 1 & 0 & -\frac{\partial F}{\partial P_M} \\ 0 & 1 & -\frac{\partial G}{\partial P_M} \\ -\frac{\partial H}{\partial k_M} & -\frac{\partial H}{\partial k_S} & 1 \end{pmatrix} \begin{pmatrix} dk_M \\ dk_S \\ dP_M \end{pmatrix} = \begin{pmatrix} \frac{\partial F}{\partial x} \\ \frac{\partial G}{\partial x} \\ \frac{\partial H}{\partial x} \end{pmatrix} dx$$

which is solved for

$$\begin{pmatrix} dk_M \\ dk_S \\ dP_M \end{pmatrix} = \frac{dx}{1 - \frac{\partial F}{\partial P_M}\frac{\partial H}{\partial k_M} - \frac{\partial G}{\partial P_M}\frac{\partial H}{\partial k_S}} \begin{pmatrix} \left(1 - \frac{\partial F}{\partial P_M}\frac{\partial H}{\partial k_M}\right)\frac{\partial F}{\partial x} + \frac{\partial F}{\partial P_M}\frac{\partial H}{\partial k_S}\frac{\partial G}{\partial x} + \frac{\partial F}{\partial P_M}\frac{\partial H}{\partial x} \\ \frac{\partial G}{\partial P_M}\frac{\partial H}{\partial k_M}\frac{\partial F}{\partial x} + \left(1 - \frac{\partial F}{\partial P_M}\frac{\partial H}{\partial k_M}\right) + \frac{\partial G}{\partial P_M}\frac{\partial H}{\partial x} \\ \frac{\partial H}{\partial k_M}\frac{\partial F}{\partial x} + \frac{\partial H}{\partial k_S}\frac{\partial G}{\partial x} + \frac{\partial H}{\partial x} \end{pmatrix}$$

where

$$\frac{\partial F}{\partial A_M} < 0,\ \frac{\partial F}{\partial A_S} > 0$$
$$\frac{\partial G}{\partial A_M} < 0,\ \frac{\partial G}{\partial A_S} > 0$$
$$\frac{\partial H}{\partial A_M} < 0,\ \frac{\partial H}{\partial A_S} > 0$$

The direct effects of technical progress is summarized as follows. As productivity grows in the manufacturing sector, both capital and labor tend to move there, The manufacturing sector is more capital intensive technical and generates more return to capital for given good prices. In order to restore the return equivalence, the capital labor ratio declines and the marginal return to capital rises in the service sector. On the contrary, as productivity grows in the service sector, both capital and labor tend to move there. Labor is more productive in the service sector than in the manufacturing sector. Technical progress in the service sector favors labor more than capital, and raises wages. In order to restore the balance, the capital-labor ratio increases in the manufacturing sector. It is natural that technical progress in the manufacturing (service) sector tends to reduce (increase) the price of the manufacturing good.

The non-direct effects are summarized as follows. If $\sigma < 1$,

$$\frac{\partial F}{\partial P_M} < 0, \ \frac{\partial G}{\partial P_M} < 0, \ \frac{\partial H}{\partial k_M} > 0, \ \frac{\partial H}{\partial k_S} > 0$$

The total effects are obtained as follows. If $\sigma < 1$,

$$\begin{gathered}\frac{\partial P_M}{\partial A_M} < 0, \ \frac{\partial P_M}{\partial A_S} > 0 \\ \frac{\partial k_M}{\partial A_M} > 0, \ \frac{\partial k_M}{\partial A_S} < 0 \\ \frac{\partial k_S}{\partial A_M} < 0, \ \frac{\partial k_S}{\partial A_S} > 0\end{gathered}$$

As a result, if the rate of substitution between manufacturing and service is less than one, as is usually assumed, technical progress in the manufacturing sector reduces the manufacturing price, increases the capital-labor ratio in the manufacturing sector, and reduces the capital-labor ratio in the service sector. Then for a given endowment of capital and labor, employment declines in the manufacturing sector, and increases in the service sector.

APPENDIX 2

The numerical results are in Table 1.

Table 1

Pm	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	0.89	0.73	0.62	0.53	0.47
$\sigma=0$		1.00	0.00	0.88	0.70	0.59	0.50	0.44
$\sigma=-0.3$		0.77	−0.30	0.87	0.70	0.58	0.50	0.44

Nm	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	0.54	0.72	0.86	0.84	0.95
$\sigma=0$		1.00	0.00	0.44	0.44	0.45	0.44	0.41
$\sigma=-0.3$		0.77	−0.30	0.41	0.39	0.41	0.38	0.34

km	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	2.70	2.39	2.16	2.19	2.05
$\sigma=0$		1.00	0.00	2.94	2.94	2.90	2.94	3.02
$\sigma=-0.3$		0.77	−0.30	3.02	3.04	3.00	3.09	3.20

ks	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	1.16	1.02	0.93	0.94	0.88
$\sigma=0$		1.00	0.00	1.26	1.26	1.24	1.26	1.30
$\sigma=-0.3$		0.77	−0.30	1.30	1.30	1.28	1.32	1.37

GDP	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	2.54	2.59	2.63	2.62	2.66
$\sigma=0$		1.00	0.00	2.52	2.52	2.52	2.52	2.51
$\sigma=-0.3$		0.77	−0.30	2.51	2.51	2.51	2.51	2.50

welfare	elasticity	σ		2.00	2.50	3.00	3.50	4.00
$\sigma=0.8$		5.00	0.80	1.36	1.58	1.85	2.12	2.41
$\sigma=0$		1.00	0.00	2.32	2.47	2.60	2.72	2.81
$\sigma=-0.3$		0.77	−0.30	1.35	1.50	1.63	1.76	1.86

Figure 9: